ESSENTIALS

OF

MEDICAL AND CLINICAL CHEMISTRY.

WITH LABORATORY EXERCISES.

BY

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ILLUSTRATED.

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PREFACE TO FOURTH EDITION.

IN this FOURTH EDITION the text has been largely re-written, especially the clinical portion, and much new matter added. Realizing the need of a brief text-book that would also serve as a practical laboratory guide, the author has, wherever the directions in the text are not sufficiently explicit, added, as foot-notes, a series of simple laboratory exercises embodying such experiments as he has had his students perform during his twenty years of medical laboratory teaching. It will be noticed that the experiments are so simple as to require only such apparatus as the general practitioner has, or should have, about his office. In keeping with the present pharmacopœia, the old spelling is retained.

Thanks for valuable assistance is extended to the author's colleagues, Drs. Solomon, Rominger and Rapp, Professors of Materia Medica, Inorganic Chemistry, and Organic and Clinical Chemistry, respectively, in the Medical Department of Kentucky University; to Dr. Harris M. Kelly, Professor of Chemistry in the Louisville Medical College, and to Dr. Jas. Lewis Howe, Professor of Chemistry in Washington and Lee University.

This edition is presented with the hope that it may meet as cordial a reception as its predecessors, and that teacher and student will find the author's labor has lightened theirs.

600 West Broadway, Louisville, June, 1900.

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ESSENTIALS OF MEDICAL AND CLINICAL CHEMISTRY.

INTRODUCTION.

" CHEMISTRY is that branch of science which treats of the composition of substances, their changes in composition and the laws governing such changes." (Webster.)

The distinctive characteristic of chemical action is change in *composition*.[1] A piece of iron may undergo many and marked changes ; it may be made hard or soft, hot or cold, luminous or non-luminous, magnetized or unmagnetized ; yet, so long as there is no modification of its composition, the change is not a chemical one, and the iron is still iron. But when it combines with other substances, as in rusting (combining with the oxygen of the air), the change is chemical and a new substance is formed which, though it contains iron, is not iron, but is entirely different in composition and properties.[2]

NOTE.—It would be well for the professor or demonstrator at each laboratory exercise to indicate beforehand, by means of the attached numbers, such of the experiments as he wishes performed. Each student should be required to have a note-book and make careful and full memoranda of everything he does.

[1] Heat pieces of platinum and magnesium wire. Note that while the platinum is unaltered, the magnesium burns (combines with the oxygen of the air) and is converted into a white powder.

[2] Suspend an ordinary hand-balance (Fig. 1) from the upper ring of the retort-stand, so that the pans are about a half inch above a note-book laid on the lower and larger ring. Weigh out one gram of powdered iron ; put it into a small dish made by bending up the edges and corners of a bit of thin

Matter is that of which the sensible universe is composed. It is *Indestructible*. Substances may undergo many changes, assume a great variety of forms, and even become invisible and fleeting gases; yet in none of these changes and combinations can a particle of matter be created or destroyed.[3]

FIG. 1.
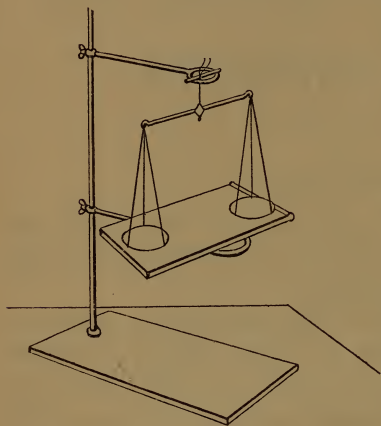
FIG. 2.
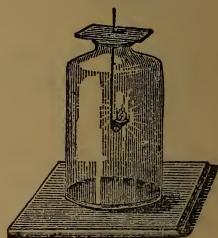
All matter has *weight*. By balances in the open air we get the *apparent weight* of a body; but to obtain the *absolute weight* it must be weighed in a vacuum where there is no air to buoy it up. (For measures of weight, see table at back of book.) But of most importance to the student of chemistry is the *specific weight* or *specific gravity*, by which we mean the weight of a substance as compared with the weight of an equal volume of some other substance specified as a standard. It is not the weight of any particular body or piece of a substance, but the relative weight of that substance or material

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sheet iron or copper; heat it until it ignites. When combustion is complete, pour it again into the scale, and note that a *new* reddish-brown substance is formed, and that the weight is *increased*.

[3] Let the instructor burn a piece of charcoal (carbon) in a jar of oxygen gas (Fig. 2). It disappears, and, so far as we can judge by the senses of sight and touch, is lost, for it has combined with the oxygen to form an invisible gas. Add lime water and shake. The gas combines with the lime and forms a white precipitate, which, if gathered and weighed, would exactly represent, besides the lime, the charcoal burned and the oxygen required to burn it.

wherever found. The standard for liquids and solids is water; for gases it is hydrogen or air. To determine the specific gravity of a liquid, divide the weight of a certain volume of it by the weight of an equal volume of water, and thus obtain the ratio.[4]

FIG. 3.

In practice we use: (a) The *specific gravity flask* (Fig. 3), made and marked to contain a certain number of grains or grams of water. Fill it up to the "scratch" on the narrow neck, with the liquid to be investigated, and weigh, deducting the weight of the flask. Divide the weight of the liquid by the marked capacity of the flask. (b) The *hydrometer* (Fig. 4), a hollow glass float with a graduated neck at the upper end indicating the specific gravity by the depth to which it sinks in the liquid.[5] This instrument is often called by other names according to its use, as "lactometer" for milk and "urinometer" for urine.

FIG. 4.

For very accurate measurements of specific gravity, the liquids must be at the standard temperature, which in this country is 60° F. or 15.5 C.

The specific gravity of solids is determined on the principle of Archimedes: *A body immersed in a liquid displaces its own volume, and loses weight equal to the weight of the liquid displaced.* Therefore, the weight a body loses when weighed in water is the weight of its own volume of water,

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[4] Procure a light vial or a small flask of 5 or 10 Cc. (1 or 2 drams) capacity, make a scratch on the neck with a file and weigh. Fill up to the scratch with water and weigh, deducting the weight of the vial. (a) Fill again with some liquid, as *alcohol*, lighter than water and weigh, deducting the weight of the vial. Divide the weight of the vialful of alcohol by the weight of the vialful of water. The resulting ratio will be the specific gravity of the alcohol. (b) Repeat the experiment, using sulphuric acid (a heavy liquid) instead of alcohol.

[5] Confirm the foregoing by using the hydrometer, first proving its accuracy by testing it in water and other liquids of known specific gravity.

and the standard with which the weight of that body must be compared.[6]

In case the body is lighter than water, a sinker is attached and

FIG. 5.
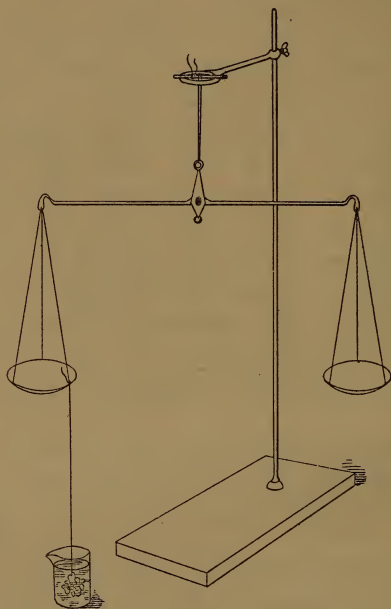
the same method pursued, except that the loss of weight of the sinker is also obtained separately, and subtracted from the total loss to ascertain the loss of weight of the lighter body.[7]

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[6] Procure a small piece of metal, as a key, or better still, an iron " jack," such as children play with, and weigh it. Next suspend it by a fine silk thread from one pan of the balance (Fig. 5) into a beaker of water, and weigh it while completely immersed. For an example we will suppose:

The piece of iron weighs........................... 150 grains.
Suspended in water it weighs...................... 130 "
Loss (or weight of its volume of water)............. 20 "
Specific gravity of the iron (150÷20).............. 7.5

[7] Secure a piece of a small spermaceti candle; weigh it alone, and then

A body soluble in water may be weighed in some liquid of known specific gravity in which it is insoluble.[8]

The specific gravity of a substance in fine particles or powder may be determined by comparing its weight with the weight of the water it displaces in a vessel of known capacity.[9]

Matter exists in one of three states, solid, liquid, or gaseous. In the solid state the particles are held together so rigidly as to give the body a definite shape ; while in the liquid state the attraction is so slight as to allow the particles to move freely upon each other and the body to take the shape of the vessel that contains it. In the gaseous state the mutual attraction of the particles is

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attach it to the piece of iron used in the previous experiment and weigh the combination, calculating the specific gravity as in the following example, in which we will suppose the candle weighs 85 grains:

The combination (iron 150 grains and candle 85 grains)
 weighs .... 235 grains.
The combination weighs in water..................... 125   "

Loss (the weight of the combination's volume of water). 110   "
Deduct the weight of the piece of iron's   "   "   " . 20   "

The weight of the candle's volume of water 90   "
 Weight of candle divided by weight of its water volume $(85 \div 90)=$
0.95==the sp. gr. of spermaceti.

[8] Make such an experiment as this : Suppose a lump of rock-candy weighs 100 grains, and in turpentine 45.62 grains. Loss= 100—45.62=54.38 grains. 100 ÷ 54.38= 1.84 the sp. gr. as referred to turpentine. Multiply this by .87, the sp. gr. of the turpentine, and we get 1.6 as the true sp. gr. of rock-candy or crystallized sugar.

[9] Weigh out 50 grains of fine, clean, dry sand, such as is sold for canary birds, and pour it into the vial used in experiment 4. Fill with water and weigh; then calculate the specific gravity of sand as in the following example, in which the vial is supposed to hold just 96 grains of water:

Weight of the sand .... 50 grains.
Weight of a vialful of water 96   "

   Total............................... 146   "
Weight of the vialful of water with the sand 124   "

Weight of the water-volume of the 50 grains of sand ... 22   "
Weight of the sand divided by the weight of its water-
 volume (50 ÷ 22 = 2.27) gives the specific gravity of
 sand 2.27

entirely overcome, and their distance from each other depends upon the pressure to which the gas is subjected. The term fluid is applied to anything capable of flowing, whether liquid o gaseous. It is highly probable that all substances, which are not decomposed by heat or cold, are capable of existing in all three states. Heat is absorbed and hence cold produced whenever the attraction between the particles is to be overcome, as in the passage of a substance from the solid to the liquid or from the liquid to the gaseous state.

When the two solids, ice and common salt, are mixed, they form a liquid, and great cold is produced.[10] Perspiration in evaporating assumes the gaseous state, and absorbs in the change so much heat that the body is kept at its normal temperature in spite of the hottest weather.[11]

On the other hand, when a substance passes from a rarer to a denser state it gives out again the heat absorbed in its passage in the opposite direction.

If we examine the infinite variety of substances upon our earth we find most of them are *compounds*, *i. e.*, they can be decomposed into two or more other substances, distinct in their properties from the substance from which they were derived and from each other. There are some substances which have never been decomposed. These are called *elements*. Only about seventy elements are at present known; but, as our methods of investigation improve, this number may be increased by the discovery of other elements, or decreased by decomposing some of those now considered elements. About one-half of these enter into the materia medica, and will be noticed in this work.

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[10] Fold tin-foil into the shape of a little dish; add powdered ice and salt. Spill a few drops of water on the table and set the dish in it. Note how quickly it is frozen fast to the table.

[11] Pour a few drops of ether into the hand and note the cold produced by its rapid evaporation. Or let the instructor put a little water in such a dish as the one just mentioned, and throw a spray of ether against the sides; the water is quickly frozen.

TABLE OF ELEMENTARY BODIES, WITH THEIR SYMBOLS AND ATOMIC WEIGHTS.

(*The more important are printed in capitals.*)

Name.	Symbol.	Atomic Weight.	Name.	Symbol.	Atomic Weight.
ALUMINUM, ...	Al	27	MERCURY (Hydrargyrum), ...	Hg	200
ANTIMONY (Stibium),	Sb	120	Molybdenum, ...	Mo	96
ARGON, ...	A	40	Neodymium, ...	Nd	141
ARSENIC, ...	As	75	NICKEL,.............	Ni	59
BARIUM, ...	Ba	137	NITROGEN, ...	N	14
BISMUTH, ...	Bi	208	Osmium, ...	Os	191
BORON, ...	B	11	OXYGEN, ...	O	16
BROMINE, ...	Br	80	Palladium,...	Pd	106
CADMIUM, ...	Cd	112	PHOSPHORUS, ...	P	31
Cæsium, ...	Cs	133	PLATINUM, ...	Pt	195
CALCIUM, ...	Ca	40	POTASSIUM (Kalium),	K	39.1
CARBON, ...	C	12	Praseodymium, ...	Pr	144
CERIUM, ...	Ce	132	Rhodium, ...	Rh	104
CHLORINE, ...	Cl	35.	Rubidium, ...	Rb	85
CHROMIUM, ...	Cr	52 5	Ruthenium,.........	Ru	101
COBALT,....	Co	59	Samarium, ...	Sm	150
Columbium (Niobium)	Cb	93	Scandium, ...	Sc	44
COPPER (Cuprum), ..	Cu	63.4	Selenium, ...	Se	79
Erbium, ...	E	166	SILICON, ...	Si	28
FLUORINE,..........	F	19	SILVER (Argentum),.	Ag	108
Gadalinium, ...	Gd	157	SODIUM (Natrium),..	Na	23
Gallium, ...	Ga	70	STRONTIUM, ...	Sr	87.5
Germanium, ...	Ge	72	SULPHUR, ...	S	32
Glucinum (Beryllium, Be)	Gl	9	Tantalum, ...	Ta	182
GOLD (Aurum),.....	Au	197	Tellurium, ...	Te	125
Helium, ...	He	4.26	Terbium, ...	Tb	160
HYDROGEN	H	1	Thallium, ...	Tl	204
Indium, ...	In	114	Thorium, ...	Th	233
IODINE, ...	I	127	TIN (Stannum),.....	Sn	118
Iridium, ...	Ir	193	Titanium, ...	Ti	50
IRON (Ferrum), ...	Fe	56	Tungsten, or Wolfram,	W	184
Lanthanum, ...	La	139	Uranium, ...	U	240
LEAD (Plumbum, ...	Pb	207	Vanadium, ...	V	51.2
LITHIUM, ...	Li	7	Ytterbium,.........	Yb	173
MAGNESIUM, ...	Mg	24	Yttrium, ...	Y	90
MANGANESE, ...	Mn	55	ZINC, ...	Zn	65
			Zirconium,..........	Zr	90

To explain the laws governing chemical phenomena, modern chemistry has adopted and greatly amplified the old atomic theory—a theory advanced certainly as far back as the ancient Greeks, for Democritus, 460 B. C., said : "The atoms are invisible

by reason of their smallness; indivisible by reason of their solid-
ity; impenetrable and unalterable."

We will take up the theories and laws, not in the order of their
enunciation, but of their natural sequence.

It is assumed that matter is composed ultimately of infinitely
small particles called *atoms;* that each element is composed of
atoms, all of a certain size, weight, etc. Atoms rarely exist alone,
but in groups called *molecules.* In an element the molecule is
generally composed of a pair of atoms of the same kind; in com-
pounds, of two or more atoms of different kinds. It has been de-
termined that equal volumes of all substances in the gaseous state,
and under like conditions, contain the same number of molecules.
So a gallon of hydrogen gas and one of oxygen gas contain the
same number of molecules, and those molecules consisting of pairs
of atoms, each gallon must contain the same number of atoms.
Furthermore, it is found that the gallon of oxygen is sixteen times
as heavy as the gallon of hydrogen. So each oxygen atom must be
sixteen times as heavy as the hydrogen atom. Hydrogen being the
lightest substance known, its *atomic weight* is taken as 1, and con-
sequently the atomic weight of oxygen is 16. The atomic weights
of other elements are determined in a similar way. By "atomic
weight" is not meant the absolute weight of atoms (for that is not
known), but the weight of the atom compared with the hydrogen
atom. The atomic weight of carbon is 12. If carbon combines
with oxygen, atom for atom, the new substance (CO) resulting
from that action will consist of molecules, in each of which the
carbon will weigh 12 and the oxygen 16, and, as the whole mass
is composed of these molecules, the same proportion obtains
throughout the new compound. So 12 is found to be the *com-
bining weight* of carbon, and 16 of oxygen. If, however, the
combination should occur in the proportion of one atom of
carbon to two atoms of oxygen, then each molecule must consist
of 12 by weight of carbon to 32 of oxygen, and that must be the
proportion throughout the entire substance.

Between these two compounds of a carbon atom with oxygen

no intermediate one can occur, for the carbon atom must take one or two, or more, oxygen atoms. It cannot take a fraction of one, for atoms are indivisible. Hence, we deduce the following Law : *Substances combine in certain fixed proportions* (atomic weights) *or in multiples of these proportions.*

Symbols are abbreviations of the names of the elements. They consist of the initial letter of the Latin name ; but if the names of several elements begin with the same letter, the single-letter symbol generally is reserved for the most common element, and for the others another letter is added. Thus, we have nine elements whose names begin with C ; the most common is carbon, whose symbol is C ; the others add other letters, as chlorine, Cl ; cobalt, Co ; copper (cuprum), Cu, etc. The symbol indicates just one atom. When more than one atom is to be represented, the number is written just after and below the symbol, thus, C_4.

Formulæ are to molecules what symbols are to elements. They indicate the kind and number of atoms composing the molecule. When more than one molecule is to be indicated, the number is placed in front of the formula, thus, $5H_2O$. A parenthesis inclosing several symbols or formulæ should be treated as a single symbol, thus, $2(NH_4)_2CO_3 = N_4H_{16}C_2O_6$.

An *equation* is a combination of formulæ and algebraic signs to indicate a chemical reaction and its results. As no matter is ever lost or created in a reaction, the number of each kind of atom before the equality sign must be the same as after it.

PART I.—INORGANIC CHEMISTRY.

CLASSIFICATION OF THE ELEMENTS.—The elements are usually divided into two great classes: (*a*) *Metals*, about fifty-five in number, possessing a peculiar lustre, good conductors of heat and electricity, and whose oxides when combined with water, form bases; (*b*) *Non-metals*, about fifteen in number, possessing but little lustre, relatively poor conductors of heat and electricity, and whose oxides combined with water form acids. The following classification is somewhat arbitrary, but convenient, and based mainly on chemical analogies, especially in valences and atomic weights.

I. Preliminary Group: Hydrogen and Oxygen.

II. Chlorine Group: Fluorine, Chlorine, Bromine, and Iodine.

III. Sulphur Group: (Oxygen) Sulphur, Selenium and Tellurium.

IV. Nitrogen Group: Nitrogen, Phosphorus, Arsenic, Antimony and Bismuth.

V. Carbon Group: Carbon, Silicon, Tin, Lead, Platinum, Iridium, Osmium, Palladium, Ruthenium and Rhodium.

VI. Potassium Group: Lithium, Ammonium, Sodium, Potassium, Rubidium and Cæsium.

VII. Calcium Group: Calcium, Strontium and Barium.

VIII. Magnesium Group: Magnesium, Zinc and Cadmium.

IX. Aluminum Group: Boron, Aluminum, Scandium, Gallium, Yttrium, Indium, Lanthanum, Cerium, Neodymium, Praseodymium, Samarium, Erbium, Ytterbium and Thallium.

X. Iron Group: Chromium, Manganese, Iron, Cobalt, Nickel, Molybdenum, Tungsten and Uranium.

XI. Copper Group: Copper, Mercury, Silver and Gold.

I. The Preliminary Group :

HYDROGEN.

OXYGEN.

The elements of this group have but little in common. Oxygen belongs to the sulphur group, while Hydrogen, the " type-element," is a group to itself ; but because of their intimate, extensive and important relations with the other elements, as well as the familiar character of their combinations with each other, we group them together as a fit beginning of the study of Chemistry.

FIG. 6.
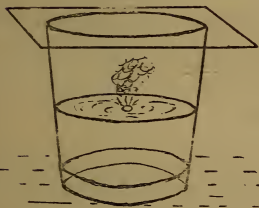
FIG. 7.
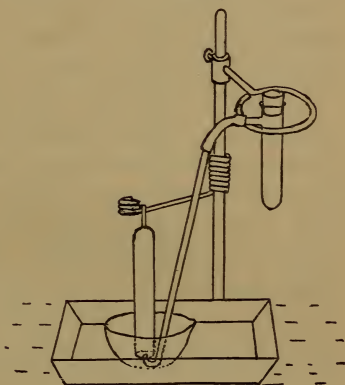
HYDROGEN (H—1).—It *occurs* in nature occasionally un-combined, as in gas-wells and volcanoes ; but in the combined state it forms one-ninth of the water on the globe, and is the base of all acids as well as a constituent of nearly all organic matter. *Prepared* in various ways from its compounds, *e. g.*, (a) by de-composing water with the electric current (see Fig. 14) ; (b) by displacing the hydrogen from water by means of metallic sodium [12] [13]

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[12] Into a tumbler half filled with water (Fig. 6) drop a piece of sodium the size of a pea. The metal melts and dances around with a hissing noise, get-ting smaller and smaller until it disappears with a sudden snap, the spattering from which should be anticipated by covering it with a piece of card-board.

[13] Repeat the above, except that the sodium is caught in a gauze spoon and

or potassium ($H_2O+Na=NaHO+H$), or by means of other metals with the aid of heat, or (c) by displacing hydrogen from acids by means of a metal, as zinc [14] ($H_2SO_4+Zn=ZnSO_4+H_2$).

Physical Properties.—A gas, transparent and colorless, and when pure, odorless and tasteless ; the lightest substance known, fourteen and a half times as light as air; hence used for balloons.[15] Very diffusible ; hence hard to keep from leaking. Acts in many respects like a metal, displacing metals in chemical compounds, seeming to form alloys with certain metals, and a conductor of electricity. Hydrogen was condensed to a liquid in 1898, by Dewar. It is by far the lightest liquid known, having a specific gravity of 0.07 ; boils at —238 C. (—396 F.), at ordinary atmospheric pressure, and at —250 C. (—418 F.), *in vacuo.*

Chemical Properties.—Hydrogen does not support ordinary combustion or animal respiration, but is not poisonous. It burns in air with a pale but very hot flame. With pure oxygen it forms the oxyhydrogen flame. This is the hottest flame known, and a stick of lime held in it glows with dazzling brilliancy, forming the calcium or Drummond light. Mixed with air or oxygen, it explodes violently on contact with a spark.[16]

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pushed down beneath the mouth of a filled and inverted test-tube, allowing the gas to bubble up in the tube and displace the water. Tubefuls may then be studied, *e. g.,* (a) Show its lightness and combustibility by turning up a tubeful a few inches beneath a flame; the gas rising and coming in contact with the flame, ignites with a slight explosion. (b) To show that it is combustible, but not a supporter of combustion, bring a lighted match to the mouth of the tube; the gas ignites and burns quietly at the open end, but the match is extinguished when passed farther up into the gas, and is relighted again as it is withdrawn.

[14] Fill a side-neck test-tube one-third full of dilute (10 per cent.) sulphuric acid; add several bits of zinc; close its mouth with a cork, and attach a delivery-tube as in Fig. 7. *Wait until the air is expelled,* and then ignite the gas as it issues, or collect it over water, and test it as in the previous experiment.

[15] Attach an ordinary clay pipe to the delivery-tube of the hydrogen generator and blow hydrogen soap bubbles; they rise in the air.

[16] Let the demonstrator fill a bladder or rubber bag with two parts of hydrogen and one of oxygen or five of air; attach a tube and blow up soap bubbles in a basin. Touched with a flame, they explode.

OXYGEN (O—16).—*Occurrence.*   Most abundant of the elements, comprising one-fifth of the air, eighth-ninths of water, one-half of the crust of the earth, and three-fourths of all organized bodies.

Preparation.—Made most easily by heating potassium chlorate

FIG. 8.
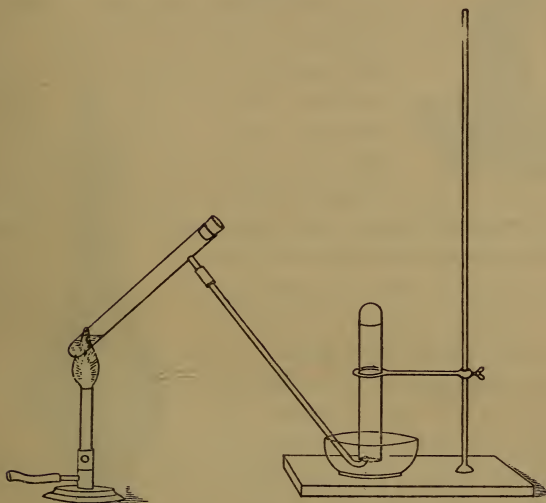
(Fig. 8), and decomposing it into potassium chloride and oxygen, thus :

$$KClO_3 = KCl + 3O.[17]$$

Physical Properties.—A colorless, odorless and tasteless gas, a little heavier (1.10 times) than air.   Under a pressure of 22.5 atmospheres and at a temperature of —136 C., it condenses into

[17] Grind in a mortar some potassium chlorate with half as much manganese dioxide, a black powder that facilitates the evolution of the oxygen.   Heat this in a side-neck test-tube as in Fig. 8, or in an open test-tube.   Recognize the oxygen by the energetic combustion when a match, or even the glowing end of the charred stick is introduced.

NOTE.—Experiments 18, 19 and 20 are to be performed by the instructor.

a colorless liquid (sp. gr. of 0.899). Water dissolves only three volumes to the hundred, but this is enough to sustain aquatic life.

Chemical Properties.—Intense affinities ; combines with every element except fluorine. The product of its action is called an *oxide*, and the process *oxidation*. Oxidation so rapid as to produce heat and light is called *combustion;* if no light, *slow combustion*. Substances that burn in air burn more brilliantly in oxygen,[18] and many substances that do not burn in air will burn in this gas.[19] By this property oxygen is usually recognized and distinguished from most other gases.

FIG. 9.

FIG. 10.

Oxygen, especially in its diluted form (air), is the great supporter of combustion, for which its abundance and universal presence eminently fit it. Combustible and supporter of combustion are only relative terms. When a combustible substance burns in a supporter of combustion the union is mutual, one being as much a party to the action as the other. A jet of air or oxygen burns

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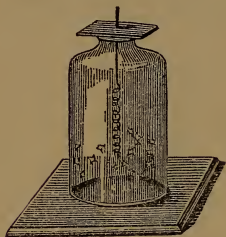
[18] A bit of phosphorus, dried by pressing between folds of blotting paper, is placed in a combustion spoon, ignited, and lowered into a jar of oxygen. The combustion is so intense that the phosphorus volatilizes, and its vapor burns throughout the jar with a brilliancy so dazzling that it is called the "phosphorus sun."

[19] A watch-spring is wound into a spiral, tipped with a bit of tinder or a piece of yarn dipped in sulphur. This is lighted and lowered into a jar of oxygen. (Fig. 9.) The iron catches fire and burns with brilliant scintillations, globules of melted iron falling and melting into the glass, unless the bottom be covered with sand or water.

as readily in coal gas as a jet of coal gas burns in air or oxygen.[20] The one in greatest abundance is usually called the supporter of combustion.

Oxidizing agents are compounds in which oxygen is held so feebly it is readily given up to substances having greater affinity for it.

Uses.—The process of respiration is a species of combustion, and, as oxygen is the best supporter of combustion, it is the best (and only) supporter of animal respiration. Administered in capillary bronchitis, œdema glottidis, etc., when the patient cannot take in a volume of air sufficient to supply the requisite amount of oxygen, it has saved many lives.

OZONE.—If through a portion of air or oxygen, electric sparks be passed, a part of the oxygen will acquire a pungent odor and peculiar properties. This may be observed about most electrical apparatus, especially X-ray machines, or, better still, the Siemens ozone tube.[21]

The same change may be induced by various chemical processes. *e. g.*, by mixing permanganate of potassium and sulphuric

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[20] Secure an ordinary lamp chimney (Fig. 10) and a wide cork to fit its lower end. Pass through the cork a narrow tube (*a*) connected by rubber hose with the house gas, and a wider one opening into the air. Turn on the coal gas and light it as it issues from the tube. The cork with the flame (not too large) is then inserted into the chimney, where it continues to burn, sufficient air entering through the wide tube (*c*). Upon turning on more gas the air is crowded out and the chimney filled with coal gas. The gas flame disappears from the tube (*a*), and an air flame appears upon the tube (*c*) as the entering air burns in the atmosphere of coal gas. The excess of coal gas may also be lighted as it escapes, showing a gas flame above and an air flame within the chimney. On lessening the flow of gas the air will again be in excess, and the flame again appear on the narrow tube (*a*). In the gas flame above the lamp chimney heat some potassium chlorate in a combustion spoon until it melts and oxygen begins to bubble up. Then lower it into the atmosphere of coal gas within the chimney. The escaping oxygen burns brilliantly, the coal gas being the supporter of the combustion.

[21] Siemens' apparatus for ozoning oxygen (Fig. 11) consists of two tubes, the inner surface of the inner and the outer surface of the outer tube being coated with tin-foil, and each connected with the poles of an induction coil or Toepler-Holtz machine. A current of oxygen passing between these tubes may be ozoned to the extent of fifteen or twenty per cent.

acid, or when phosphorus partially covered with water is exposed to the air. This modified oxygen is called *ozone*. It is one and

FIG. 11.
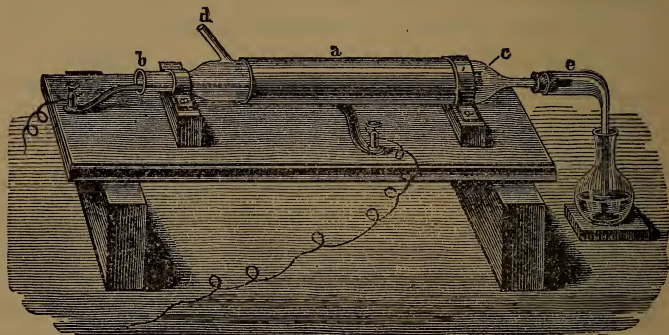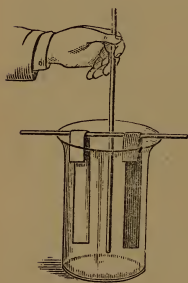
a half times as heavy as ordinary oxygen, for its molecule contains three instead of two atoms. Very energetic, oxidizing substances unaffected by ordinary oxygen. Oxidizes potassium iodide with liberation of iodine, hence its *test :* paper dipped in a solution of potassium iodide and starch is colored blue in the presence of ozone.[22] Ozone is found in the air, especially after thunder storms, and when present in considerable amount (as much as .00005 per cent.) is apt to irritate the respiratory tract ; but by oxidizing infecting germs, etc., it prevents the spread of infectious diseases.

FIG. 12.

The various preparations known as "ozonized ether," "ozonized water," "pyrozone," etc., are mainly solutions of hydrogen dioxide.

---

[22] Into a beaker place some crystals of potassium permanganate. Suspend on a glass rod, as in Fig. 12, a strip of ozone test-paper, and beside it a strip of plain white paper for comparison. Pour from a pipette on the crystals a few drops of sulphuric acid. Cover with a card-board, and note the gradual blueing of the test paper by the ozone.

COMPOUNDS OF HYDROGEN AND OXYGEN. — Two of these are known :

Hydrogen Monoxide, H_2O.
Hydrogen Dioxide, H_2O_2.

HYDROGEN MONOXIDE OR WATER.—*Occurrence*.—Water is seen almost everywhere in nature, yet much is invisible, as in the air,

FIG. 13.
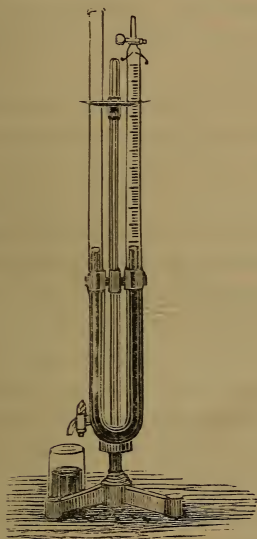
FIG. 14.

and hidden, as in crystals, etc.; it constitutes the major part of all plants and animals.[23]

Physical Properties.—Transparent, colorless, odorless, tasteless liquid. Below 32° F. (0° C.) it is a solid (ice), and above 212° F. (100° C.) a vapor (steam or vapor of water). In solidifying,

---

[23] Melt a 5-inch piece of glass tubing into two portions, and then heat the closed ends, and blow them into slight bulbs. Into one introduce a bit of match stick and heat. Note (*a*) water of constitution, (*b*) residue, and (*c*) that this is destructive distillation.

water expands; so ice floats. The boiling-point is higher than 212° F. under increased pressure or when it contains solid matter in solution; and lower than 212° F. when the pressure is diminished as in vacuum-pans and at high altitudes.

Chemical Properties. — The chemical composition of water may be proved by (*synthesis*) combining its constituents $(H_2 + O = H_2O)$[24] or by (*analysis*) passing the galvanic current through water until it is decomposed into its component gases $(H_2O = H_2 + O)$.[25] Neutral in reaction; combines with the oxides of the metals to form hydrates (bases), and with the ·oxides of the non-metals to form acids.

Uses.—Water is the greatest of all solvents, and thus performs an important function in the economy of nature and human arts. It is the vehicle by which all foods and drugs must reach the tissues and the waste products leave them. Most chemicals are used in aqueous solutions, and medicines are generally administered dissolved with water. The watery solution of a fixed substance is called a "*liquor*," and of a volatile substance an "*aqua*."

One body is said to dissolve in another when they coalesce and their particles intimately mingle. This is possible only in the liquid and gaseous states. When a substance dissolves it takes on the physical state of the solvent, *e. g.*, a solid or gas dissolving in water becomes a liquid and then mixes with the water, the gas elevating the temperature and the solid lowering it. Heat assisting the liquefaction of a solid, and opposing that of a gas, generally hastens the solution of the one and retards that of the other. Many solid substances when separating from a solution take with them, as a necessary part of the crystal, a certain definite amount of water— *water of crystallization*. This water does not modify the chemi-

NOTE.—Experiments 25 and 26 had best be performed by the instructor.

[24] A mixture of two volumes of hydrogen and one of oxygen exploded in a eudiometer (Fig. 13), produces only water.

[25] Fill the apparatus shown in Fig. 14 with water acidulated with sulphuric acid. Connect with a battery. The electricity passing through the water decomposes it into two volumes of hydrogen which collects in one tube and one volume of oxygen in the other.

cal nature of the substance, but is necessary for maintaining the crystalline form. If the crystal loses its water of crystallization by heat or exposure, it *effloresces* into an amorphous powder.[26] Some substances when exposed absorb water from the air and *deliquesce* (melt down).

Natural Waters are never pure, since water dissolves more or less of almost everything it touches ; the air through which it falls as rain, the surfaces over which it flows and the strata through which it percolates, each adding its quota to the contamination. Good, potable (drinkable) water should be cool, clear and odorless, with just gases and solids enough in solution to give it an agreeable taste, neither flat, salty nor sweetish, and should dissolve soap without an appreciable curd. Yet a water may be all this and be unpotable from the presence of poisonous and infectious contamination. Rain and snow water are the purest of natural waters, except in the neighborhood of large cities where the air is impure and the roofs dirty. Melted ice is purer than the water from which it is formed, since most of the dissolved solids remain in the unfrozen water ; but the suspended matters are retained, many of the bacteria, especially typhoid, passing through the ordeal uninjured. Like boiled water it has a flat taste from the loss of dissolved gases. Most cities get water from rivers and lakes, while country people usually obtain theirs from springs and wells. Well water in cities, and even in small towns where the ground is more or less saturated with filth from cess-pools, drains and surface accumulations, is always more or less contaminated and dangerous, though its sparkle and agreeable taste often commend it to those using it. A well is often what Larrabee used to call "a perpendicular drain," and is especially dangerous if shallow. Deep wells are such as are 100 feet or more in depth or draw their water from beneath a stratum of impervious clay or rock. These waters from contact with the earth contain min-

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[26] Into the other tube drop a small crystal of $CuSO_4 5H_2O$. Heat gently and note (a) water condensed in cooler part of the tube and (b) the residue is amorphous.

eral matters, especially salts of calcium and magnesium, making them more or less hard. The character of the mineral impurities is easily determined by their appropriate tests, and the total amount estimated by evaporating carefully (over a water-bath) a certain volume of the water and weighing the residue, which should never be over 30 or 40 grains to the gallon. But a vastly more important and dangerous contamination is organic, especially nitrogenous and animal matters; not that these organic matters are themselves so dangerous, but that they form a favorable soil, a nidus for the development and growth of various infecting germs that may be implanted therein, as during epidemics of cholera, dysentery and typhoid fever. Such water is a prolific source of disease, and its use is never safe. The recognition of the presence, number and character of these organisms is the province of the bacteriologist and requires such special care and skill, and offers so many difficulties that chemical methods are usually relied on to show the presence of the organic matter without which the germs cannot exist.

The more exact methods of testing for organic contamination are so complex that they are practicable only to the chemist, but the physician may easily do it in a rough and ready way :—

(*a*) Half fill a clean bottle with the water; warm, agitate and critically smell it; a foul odor indicates organic impurity.

(*b*) To 100 Cc. of the water add 1 Cc. of sulphuric acid; warm and add a few drops of a 1 per cent. solution of potassium permanganate; the rose color imparted by the latter is destroyed if organic matter be present.[27]

Mineral Waters are such as possess real or supposed special therapeutic value, and may be classed as follows :

(*a*) *Carbonated*, those charged with carbonic acid (carbon dioxide).

---

[27] Various substances other than organic matter will produce the same effect, but since they are usually produced from the oxidation of nitrogenized and sulphurized organic matter they too point to previous pollution.

(*b*) *Sulphur*, containing some soluble sulphide, especially hydrogen sulphide.

(*c*) *Alkaline*, those containing soluble alkalies such as carbonates or bicarbonates of sodium and potassium.

(*d*) *Lithia*, such as contain salts of lithium, even when in very small amount, and associated with other substances.

(*e*) *Saline*, those containing neutral salts such as the chlorides, bromides and sulphates of sodium, magnesium, etc.[28]

(*f*) *Chalybeate*, which contain some compounds of iron, usually the carbonate held in solution by carbon dioxide and depositing when that gas is lost on exposure to the atmosphere.

(*g*) *Thermal* or natural hot waters; useful mainly for baths.

Many waters belong to more than one class, as alkaline-carbonated, alkaline lithia, etc.

PURIFICATION OF WATER.—Natural waters may be purified by

(*a*) *Boiling*, which sterilizes the water by destroying the living organisms and precipitates the carbonates of calcium, magnesium and iron by driving off the carbon dioxide holding them in solution.

(*b*) *Filtration*, that is, passing it through some clean, insoluble, porous substance as paper, charcoal, sand, brick, stone or unglazed earthenware. Some filters, if well made and clean, will remove not only the suspended matters, but a considerable portion of the dissolved organic substances. Filters of unglazed porcelain are sold which remove all micro-organisms and yield a water perfectly sterile. Many cities now have their water supplies filtered through clean, sharp sand; and experiments have shown that "A sand filter 5 feet thick and filtering two million gallons per acre a day will remove 99.98 per cent. of the bacteria," and that the most polluted waters can thus be rendered almost harmless.

(*c*) *Distillation* in which the water is boiled and its vapor

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[28] *Sea water* is a saline water containing about $3\frac{1}{2}$ per cent. of mineral matter, mainly sodium chloride, with smaller quantities of other mineral salts.

passed through a block-tin or glass condenser as shown in Fig. 15, and recondensed and gathered in a clean vessel.[29]   Where

FIG. 15.
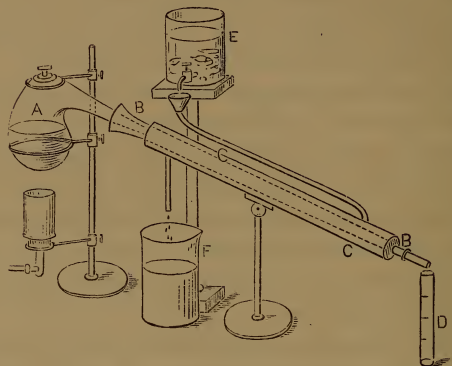
great purity, is required as in the preparation of the officinal distilled water (aqua destillata U. S. P.), the first 10 per cent. is rejected as liable to contain the gaseous impurities, and the last 10 per cent. left in the boiler, lest some of the more volatilizable solids come over with it.[30]

HYDROGEN DIOXIDE.—Peroxide of Hydrogen (H_2O_2). Prepared most easily by passing CO_2 through barium dioxide in suspended in water, thus:

$$BaO_2 + CO_2 + H_2O = BaCO_3 + H_2O_2,$$
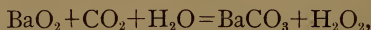
or commercially by hydrofluoric acid thus:

$$BaO_2 + 2HF = BaF_2 + H_2O_2.$$

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[29] Dissolve 1 Gm. of CuSO in water and boil in a stoppered side-neck test-tube (Fig. 16) introducing the delivery tube into a clean test-tube set in a beaker of crushed ice.   Note the absence of taste, color, etc., in the distillate.

[30] If a solid be so treated the process is called *sublimation* instead of distillation; and the product is a *sublimate* instead of a distillate.   When a mixture of two or more liquids is distilled, the one having the lowest boiling point comes over first, leaving the others behind; and the process is called *fractional distillation*, but the separation is seldom complete.

The insoluble barium salt may be allowed to subside, and the clear aqueous solution of H_2O_2 poured off. It is sold in various strengths, according to the number of volumes of oxygen a certain volume of the solution will yield, the ten-volume solution being most employed. The so-called "Ozonized ether" is made by shaking this solution with ether, which extracts the hydrogen dioxide.

Properties.—When concentrated, hydrogen dioxide is a colorless, syrupy liquid of pungent odor and taste, and decomposes so easily into $H_2O + O$ that it must be kept in a cool place, well bottled, in acid solution, away from contact with organic matter, and agitated as little as possible.

Uses.—Being an active oxidizer,[31] it is a valuable bleaching agent,[33] especially for woolen fabrics, and is largely sold as blondine for bleaching the hair. As it destroys bacteria and dissolves pus, etc., it is used very abundantly in medicine and surgery to cleanse ulcers and abscesses, and to dissolve the membranes of scarlet fever, diphtheria, etc. As it effervesces with pus,[34] it is used as a test for pus in the urine.

RADICALS.—Every molecule is composed of two parts, called *radicals*, held together by chemical affinity. Both radicals may be elements, as in H—Cl, or one may be elementary and the other compound, as H—NO_3, or both compound, as NH_4—NO_3. Some compound radicals can be isolated, *e. g.*, by heat: Hg—CN=Hg+CN. Others decompose whenever set free.

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[31] Take a little hydrogen dioxide solution, add a drop each of potassium chromate and sulphuric acid and a little ether, and shake; the potassium chromate is oxidized with the production of blue perchromic acid.

[32] Secure an old painting darkened with age, or an old engraving yellowed and soiled; wash it with hydrogen dioxide, and note the brightening effect.

[33] Dip a strip of ozone test paper into a solution of hydrogen dioxide, and note that it is not blued until a few drops of ferrous sulphate is added to act as an oxygen carrier.

[34] Add hydrogen peroxide to milk in test-tube and note effervescence, the cells in the milk acting as would pus corpuscles.

Often when a galvanic current is passed through a com-
pound, the chemical affinity is overcome by the electricity,
and the molecule separates into its two radicals, one of
which goes to the positive and the other to the negative
pole.[35]   Unlike electrical conditions attract, so the radical
going to the negative pole must be *electro-positive*, and the
one going to the positive pole *electro-negative*.   The metallic
radicals are relatively electro-positive and the non-metallic
electro-negative.

Some radicals are more intensely electro-negative or
electro-positive than others.   In the following list the more
common elements are so arranged that each is usually posi-
tive to those following it and negative to those preceding :

Positive end : +K, Na, Mg, Zn, Fe, Al, Pb, Sn, Bi, Cu, Ag, Hg,
          Pt, Au, H, Sb, As, C, P, S, N, I, Br, Cl, F, O.—Negative end.

A radical is electro-positive or electro negative only in its
relation to other radicals ; for while C is positive to O, it is
negative to K.

In formulæ the electro-positive radical is written first and
the electro-negative next.

The greater the difference between the electrical condi-
tion of two radicals, the greater the energy with which they
unite and the more stable the product, and *vice versâ ; e. g.*,
O has a strong affinity for K, a weak one for Cl, and will
not unite with F under any circumstances.   An idea once
prevailed that the relation of affinities were fixed and con-
stant between the same substances, and great pains were
taken to construct tables similar to the above to show what

---

[35] Into a jar put some water ; add solutions of red litmus, potassium
iodide, and boiled starch ; connect with the galvanic battery.   The
electric current decomposes the potassium iodide into *iodine*, which
gathers at the positive pole, producing a blue color, with the starch, and
potassium at the negative, where it produces alkali, turning the red
litmus blue.

was called the "precedence of chemical affinities." These tables showed the order of affinities for the circumstances under which the experiments were made, and nothing else.

The circumstances attending chemical reactions are so complicated that in many cases it is impossible to predict the precedence of affinities and the result of an untried experiment.

Among these modifying causes may be mentioned:

1. *Temperature*, changes of which often reverse chemical affinities. Moderately heated, mercury and oxygen will readily combine, but when highly heated their affinity is destroyed, and they will refuse to unite, or, if already combined, will separate.

Ordinarily free carbon has no affinity for oxygen, but at high temperatures it surpasses most other elements in its greediness for that substance, even taking it from a metal so extremely electro-positive as potassium.

2. *Volatility.*—*Whenever in a mixture of two or more substances it is possible, by a re-arrangement of the radicals, to form a compound volatile at the temperature of the experiment, such re-arrangement will occur and the volatile compound be formed.* For example:

$$FeS + H_2SO_4 = FeSO_4 + H_2S \; ; \; or,$$
$$2NH_4Cl + CaCO_3 = (NH_4)_2CO_3 + CaCl_2 \; ; \; or,$$
$$H_3BO_3 + 3NaCl = 3HCl + Na_3BO_3.$$
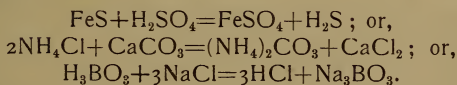
3. *Insolubility.*—*Whenever, on mixing two or more substances in solution, it is possible, by re-arrangement of the radicals, to form an insoluble compound, that re-arrangement will occur and the insoluble compound be formed as a precipitate.* For example:

$$CaCl_2 + (NH_4)_2CO_3 = CaCO_3 + 2NH_4Cl.$$
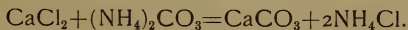
It is especially important to remember this principle, for its application in tests, incompatibilities, and antidotes.

4. *Nascent State.*—Ordinarily the atoms of an element are

grouped in pairs, and hence somewhat indifferent to the attractions of other atoms ; but just as they are being liberated (born) from a compound they are alone, and each atom, having no fellow, readily enters into combination with any atom it meets. This state is called *nascent* (*nasci*, to be born).

5. *Catalysis.*—This is the name given to the unexplained influence exerted by some substances of inducing chemical reactions between other substances without themselves undergoing any change.

The VALENCE of a radical is its combining value, or its value in exchange for other radicals.[36] Here again hydrogen is taken as the standard. A radical that combines with or takes the place of one atom of hydrogen is said to be *univalent* (one valued); of two atoms, *bivalent;* three, *trivalent;* four, *quadrivalent;* five, *quinquivalent;* six, *sexivalent.* The valence is indicated by a Roman numeral just above and after the radical, thus: $(NH_4)^I$, Ca^{II}, $(PO_4)^{III}$, Si^{IV}, As^V, S^{VI}. The two radicals of every saturated compound must possess an equal number of valences. Hence,

In HCl the radical Cl is equivalent to 1 atom of hydrogen;
In H_2O the radical O is equivalent to 2 atoms of hydrogen;
In NH_3 the radical N is equivalent to 3 atoms of hydrogen;
In CH_4 the radical C is equivalent to 4 atoms of hydrogen.
Therefore Cl is univalent, O bivalent, N trivalent, and C quadrivalent.

The same regard for valence is observed when radicals are made to displace each other, thus: H $(SO_4)^{II}$ requires two atoms of K^I or one of Zn^{II} to form $K^I_2(SO_4)^{II}$ or $Zn^{II}(SO_4)^{II}$.

Some elements exercise more than one valence : *e. g.,* mercury may be univalent, as in HgI, or bivalent, as in

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[36] The student should bear in mind that valence has nothing to do with the combining weight or the chemical activity of an element.

HgI_2; or iron may be bivalent, as in $FeCl_2$, or trivalent, as in $FeCl_3$. The termination "*-ous*" is given to those compounds in which the positive element exercises its lower valence, and "*-ic*" to those in which the higher valence is exercised, as $FeCl_2$, ferrous chloride; and $FeCl_3$, ferric chloride.

In the following table the most commonly occurring simple or elementary radicals are arranged according to their valences:

TABLE OF VALENCE.

I.	II.	III.	IV.	V.	VI.
F, Cl . .	Ba, Sr . .	Al	C, Si . .	. .	. .
Br, I . . .	Ca, Mg .	Au	Pt	. .	. .
H, Ag, . .	Cd, Zn . .	Bo	. .	. .	. .
.	O	. .	. .	. .	. .
K, Na, . .	Pb, Sn . .	. .	Pb, Sn . .	. .	. .
(NH₄), Li,	S, Se . .	Fe, Cr . .	. .	. .	S, Se . . .
.	Fe, Cr . .	Mn, Co .	. .	. .	. .
. .	Mn, Co .	Ni	. .	. .	. .
. .	Ni	. .	. .	. .	. .
. .	. .	N, P .	. .	N, P . . .	. .
. .		Bi, Sb, As.	. .	Bi, Sb, As.	. .
Cu, Hg . .	Cu, Hg .	. .	. .	. .	. .

The next table shows the valences, together with the symbols and formulæ, of the most common electro-negative (acidulous) radicals:

Univalent Radicals.
- Cl is the negative radical of all chlorides.
- Br is the negative radical of all bromides.
- I is the negative radical of all iodides.
- CN is the negative radical of all cyanides.
- HO is the negative radical of all hydrates.
- NO_3 is the negative radical of all nitrates.
- ClO_3 is the negative radical of all chlorates.
- $C_2H_3O_2$ is the negative radical of all acetates (Ac.)

Bivalent Radicals.
O is the negative radical of all oxldes.
S is the negative radical of all sulphides.
SO_3 is the negative radical of all sulphites.
SO_4 is the negative radical of all sulphates.
CO_3 is the negative radical of all carbonates.
C_2O_4 is the negative radical of all oxalates (Ox.).
$C_4H_4O_6$ is the negative radical of all tartrates (T.).

Trivalent Radicals.
$C_6H_5O_7$ is the negative radical of all citrates (Cit.).
PO_4 is the negative radical of all phosphates.
BO_3 is the negative radical of all borates.

FORMULÆ—In constructing formulæ, (a) write the positive radical first and the negative second, thus: Ba Cl; and (b) make their valences balance, thus: Ba Cl_2; for in every saturated compound each radical must possess the same number of valences.

NOMENCLATURE—In naming a formula, give the simple name of the positive radical first, and then the name of the negative radical with the termination " -ide," if the negative radical be an element, thus:

$$Na^I\ Cl^I\quad Ca^{II}\ Br^I_2$$
Sodium Chlor-*ide ;* Calcium Brom-*ide ;*
$$Al^{III}_2\ O\ _3\quad Pt^{IV}\ I\ _4$$
Aluminum Ox-*ide ;* Platinum Iod-*ide.*
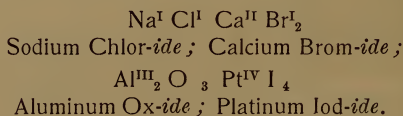
But if the negative be a compound radical, *i. e.,* one in which another element, as oxygen, is associated with the leading negative element, the termination is *"-ite"* or *"-ate,"* according to whether the negative element exercises its lower or higher valence, taking less or more oxygen, for example:

$$Na\ ClO_2\quad Na\ ClO_3$$
Sodium Chlor-*ite ;* Sodium Chlor-*ate ;*
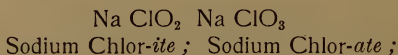
If the negative element exercises a still lower or a still higher valence, and takes still less or still more oxygen? the prefix " hypo- " is used for the lowest and prefix " per- " for the highest, thus :

Na ClO   ;   Na ClO$_2$
Sodium *hypo*-chlo-*ite ;* Sodium chlor-*ite ;*

Na ClO$_3$;   Na ClO$_4$
Sodium chlor-*ate ;* Sodium *per*-chlor-*ate.*
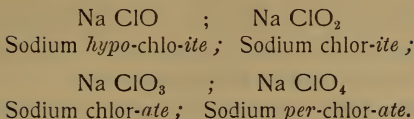
NOTE.—The student should refer to the tables of valences on the preceding page, and practice combining positive radicals with negative ones until he can construct readily all the ordinary inorganic formulæ. The teacher should persistently drill the class in this exercise, for its mastery removes one of the biggest of all bug-bears to the beginner in chemistry. It is best for the teacher to confine himself for the present to the simple system of nomenclature given above, ignoring confusing irregularities and exceptions, and obsolete synonyms, till he shall come to describe the various chemical substances themselves.

II. The Chlorine Group.

Name.	Derivation of Name.	Symbol.	At. Wt.
FLUORINE,	Fluor spar,	F,	19
CHLORINE,	χλωρός, green,	Cl,	35.5
BROMINE,	βρῶμος, stink,	Br,	80
IODINE,	Ἰώδης, violet,	I,	127

The members of this group are all univalent and much alike in

FIG. 16.
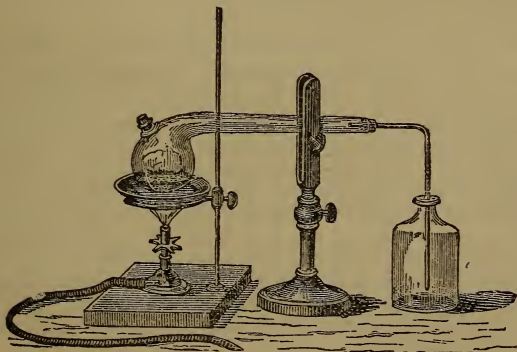
their sources and physical and chemical properties. They differ in degree rather than in kind, forming a graded series. Hence we will consider them all together.

Sources.—Never free in nature. The principal source of fluorine is fluor spar (CaF_2), while compounds of chlorine, bromine and iodine occur in sea and other salt waters.

Preparation.—Free fluorine is obtained only with great difficulty; the others may be prepared by removing the hydrogen from their hydrogen salts (hydracids) by means of oxygen derived from manganese dioxide,[37] thus :—

$$4HCl + MnO_2 = MnCl_2 + 2H_2O + Cl_2.$$
$$4HBr + MnO_2 = MnBr_2 + 2H_2O + Br_2.$$
$$4HI \ + MnO_2 = MnI_2 \ + 2H_2O + I_2. \quad [38]$$
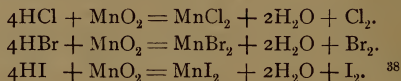
Physical Properties.—Fluorine is a nearly colorless gas, with properties resembling chlorine, but more intense. Chlorine is a very irritating yellowish-green gas, two and a half times as heavy as air, slightly soluble in water (three volumes), forming "*Aqua chlori*, U. S. P." Bromine is a red liquid, giving off red vapors of a disagreeable, irritating odor; very slightly soluble in water.

Iodine is a solid, in bluish-gray scales, which, when warmed, give off violet vapors; practically insoluble in water except by the intervention of an alkaline iodide ;[42] soluble in alcohol; irritating, even caustic.

Chemical Properties.—Intensely electro-negative; great affinity for the metals,[40] especially hydrogen.[41] In negativeness, and con-

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Experiments 40 and 41 had best be performed by the instructor.

[37] Into a flask standing in a dish of water warmed over a heater and the whole apparatus (Fig. 16) under a hood, pour several ounces of HCl and half as much MnO_2 in lumps, and agitate. The gas passes out, and being heavier than air, collects in the bottle, where its yellowish green color makes it visible.

[38] To each of three small test-tubes add a few grains of manganese dioxide. To the first add a few crystals of Na Cl, to the second, of K Br, and to the third, of K I. Add a few drops of strong H_2SO_4 and warm. Note the evolution of Cl from the first, Br from the second, and I from the third, and study the properties of each, taking care not to inhale them, and stopping the reaction as soon as the test is finished.

[39] To a little chlorinated lime (bleaching powder) in a test-tube, add some dilute acid and note the evolution of Cl.

[40] Into a jar of chlorine introduce some copper or bronze foil, or sprinkle some powdered antimony. They inflame spontaneously.

[41] (*a*) Into a jar of chlorine lower a lighted candle. The hydrogen of the

sequently in affinity for the metals, F is greatest, Cl next, Br next, and I least. Therefore, in compounds with the metals, F will displace Cl, and Cl will displace Br, and either F, Cl, or Br will displace I.[42] These elements destroy coloring matters and noxious effluvia in two ways: (1) by abstracting their hydrogen; (2) by abstracting the hydrogen of water, setting free nascent oxygen, which oxidizes the matters in question.[43]

Medical.—Chlorine gas and bromine vapor are used for disinfection. Inhaled they cause severe coryza and bronchitis. Taken into the stomach, bromine and iodine cause gastro-enteritis. The antidote is boiled starch. Locally bromine is used as an escharotic and iodine as a counter-irritant.

Pharmaceutical.—The following preparations are officinal: *Tinctura Iodi* (7 per cent.); and *Liquor Iodi Compositus* (Lugol's Solution) (Iodine 5, potassium iodide 10, and water 100). The so-called *colorless tincture of iodine* is made by adding ammonia-water to the tincture until it is decolorized by converting the iodine into ammonium iodide.[44]

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tallow burns in the chlorine to form hydrochloric acid, and all the carbon is liberated as smoke. (*b*) Into a similar jar thrust a piece of paper dipped in warm turpentine. It inflames spontaneously and burns, evolving dense clouds of smoke.

[42] Take two large test-tubes half full of water. Into one put a grain of potassium bromide, into the other potassium iodide; add chlorine-water to each. The chlorine will liberate the bromine in one and the iodine in the other. This may be shown (*a*) by their color; (*b*) by adding a few drops of carbon bisulphide or chloroform, which on agitation will gather all the free bromine and iodine, and be colored brown with the one and violet with the other; or (*c*) by adding a few drops of starch-water, which will give brown with bromine and a deep blue with iodine.

[43] (*a*) Into one bottle of chlorine gas introduce a piece of dry calico, into another a moist piece. The moist calico is rapidly bleached, while the dry is but slowly affected. (*b*) To a solution of indigo, cochineal, or some aniline color, add chlorine water. It is immediately decolorized.

[44] Put a crystal of iodine in each of three small test-tubes, to the first add some water, to the second, alcohol, and to the third, a solution of potassium iodide; note it is very slightly soluble in water but readily so in alcohol and in a solution of potassium iodide. Put a drop of the alcohol solution (tincture) on the hand and note the brown stain. To each of the test-tubes add a few drops of ammonia water or liquor potassæ and note the disappearance of the brown color.

Tests.—In the free state chlorine and bromine may be known by their bleaching, color, odor, etc. Iodine is recognized by the blue color it strikes with starch.

ACIDS.—Just as in the world at large, the balancing of forces is due to a general struggle between opposite and antagonistic qualities, as between light and darkness, heat and cold; so the chemical status seems to be a resultant of the antagonism of the opposing "positive" and "negative" within the molecule. If the positive radical predominates over the negative, this excess of positiveness gives the compound an alkaline character; while on the other hand a predominance of the negative over the positive gives it an acid character. Thus an excess of negativeness or of positiveness finds expression in the compound as acidity[45] or alkalinity.[46]

Since H is the weakest of all positive radicals, it is over it that strong negative radicals predominate most completely; so that the hydrogen salts are as a class the most acid[47] in all chemistry, in fact they are called *the acids.*

Acids may be divided into two classes:

(*a*) *Hydracids* which are the " -ide " salts of hydrogen, the negative radicals consisting only of a single element.

(*b*) *Oxacids* in which the negative element has oxygen associated with it, forming a compound negative radical. The acids are given a somewhat special nomenclature, the main portion of which is derived from the name of the

---

[45] Acid substances may be recognized by their usually having a sour taste, by redding certain vegetable coloring matters, such as litmus, and by neutralizing alkalies.

[46] Alkaline substances generally have a soapy taste and neutralize acids, and restore to the original color vegetable matters reddened by acids.

[47] Hydrogen hydrate (HHO) or water is one salt of hydrogen that is not acid. The radical HO being as weakly negative as H is weakly positive, neither predominates, and water is neutral.

negative element. Hydracids are given the prefix "hydro-" and the termination "-ic." The oxacids conform to the regular nomenclature except that the word "acid" is used instead of the name of the positive radical, hydrogen, and the terminations "-ate" and "-ite" become "-ic" and "-ous" respectively. These rules are illustrated in the little table of chlorine acids given below. The oxacids are generally considered as formed by the combination of water with the oxides of the negative element, the different oxides being distinguished by prefixes derived from the Greek numerals indicating the number of oxygen atoms, thus:

Cl_2O—Chlorine Monoxide.
Cl_2O_2 (?)—Chlorine Dioxide.
Cl_2O_3—Chlorine Trioxide.
Cl_2O_4—Chlorine Tetroxide.
Cl_2O_5—Chlorine Pentoxide.
Cl_2O_7—Chlorine Heptoxide.

The following table illustrates the formation and nomenclature of the chlorine acids:

$Cl_2O + H_2O = 2HClG$—Hydrogen Hypochlorite—Hypochlorous acid.
$Cl_2O_3 + H_2O = 2HClO_2$—Hydrogen Chlorite—Chlorous acid.
$Cl_2O_5 + H_2O = 2HClO_3$—Hydrogen Chlorate—Chloric acid.
$Cl_2O_7 + H_2O = 2HClO_4$—Hydrogen Perchlorate—Perchloric acid.

THE HYDRACIDS of the chlorine group are as follows:—

$H + F = HF$—Hydrogen Fluoride—Hydrofluoric acid.
$H + Cl = HCl$—Hydrogen Chloride—Hydrochloric (muriatic) acid.
$H + Br = HBr$—Hydrogen Bromide—Hydrobromic acid.
$H + I = HI$—Hydrogen Iodide—Hydriodic acid.

Prepared by treating the appropriate salt with H_2SO_4, thus:—

$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$
$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$[48]
$2KBr + H_2SO_4 = K_2SO_4 + 2HBr.$
$2KI + H_2SO_4 = K_2SO_4 + 2HI.$

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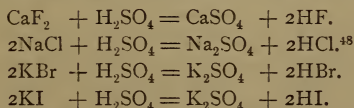
[48] To prepare hydrochloric acid gas, put several ounces of common salt and

4

Physical Properties.—Colorless, irritating gases; sharp, sour taste;[49] very soluble, water dissolving several hundred times its own volume, forming *aquæ* known by the simple name of the acid itself, thus: The officinal " hydrochloric acid " is a solution of the hydrochloric acid gas in water.

Fig. 17.
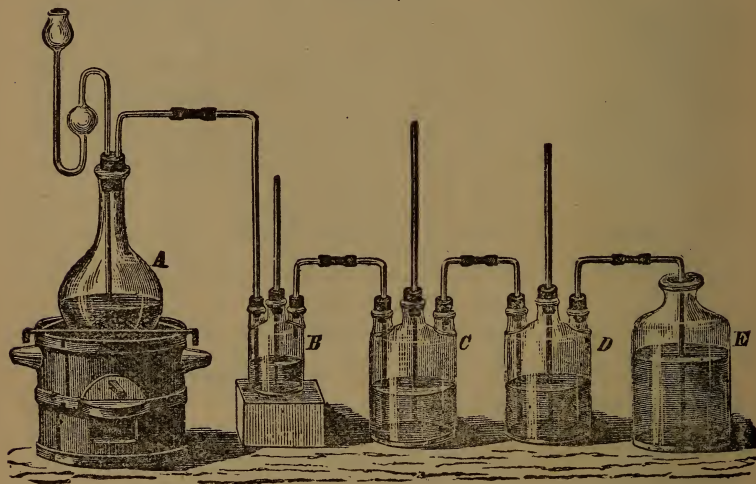
Chemical Properties.—Strong acids; true acids even without water.

Uses.—*HF* attacks silica energetically, hence is used to etch glass; very poisonous, and burns made by it heal with difficulty.

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about twice as much sulphuric acid into a flask, and warm. The gas comes off in abundance and may be collected in a dry bottle (like chlorine, Fig. 16), or over mercury. The solution of the gas (the ordinary form) is obtained by passing the gas through a series of Wolff bottles containing cold water and arranged as shown in Fig. 17. For making HBr or III, phosphoric acid is better, since sulphuric is apt to be partially reduced with evolution of SO_2.

[49] Fill a large dry glass tube with HCl gas and quickly invert it in a dish of water colored blue with litmus. Note that the gas is instantly dissolved and that the water rushes up to take its place and the litmus is reddened by the acid. Let some of the gas pour into the mouth and note sour taste.

HCl is very useful in the arts. *Aqua regia*, or nitro-muriatic acid, is a mixture of nitric and hydrochloric acids. It is the best solvent of gold[50] and platinum. The metals are attacked by the nascent chlorine which is evolved when the H of the HCl is oxidized by the O of the HNO_3. In medicine HCl is often prescribed as a tonic.

HBr, like all bromides, is a sedative. *HI*, like all iodides, is an alterative.

Tests.—Fluoride $+ H_2SO_4$—etches glass.[51]-[52]

Chloride $+ AgNO_3$—white precipitate, soluble in ammonia.

Bromide $+ AgNO_3$—yellowish-white precipitate, slightly soluble in ammonia.

Iodide $+ AgNO_3$—yellow precipitate, insoluble in ammonia.[53]

If to a bromide or iodide some chlorine-water and starch paste be added, the bromine and iodine will be liberated, the bromine striking a brown and the iodine a blue color with the starch.

OXYSALTS *of the Chlorine Group.*—The members of the chlorine group are so electro-negative that they have but little affinity for oxygen, it being also strongly electro-negative. Bromine has for

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[50] Take two beakers and put into one 5 Cc. of HCl and into the other 2 Cc. of HNO_3. Add to each a sheet of gold-leaf. Note that the gold-leaf is unaffected. Now pour the contents of one beaker into the other and note that the gold-leaf is dissolved in the mixed acids (aqua regia).

[51] On a plate of glass coated with wax or copper-plate varnish (six parts of mastic, one of asphalt, and one of wax dissolved in turpentine) draw a design with a pointed instrument. Invert over a lead dish containing powdered CaF_2 moistened with strong H_2SO_4 and warm gently. Hydrofluoric acid gas is evolved and attacks the glass wherever the wax has been scratched off. Upon removing the wax the design is found permanently etched on the glass.

[52] To a small lead dish about the size of a watch crystal, such as any tinner can stamp out of sheet lead, add 5 grains of CaF_2 and moisten with strong H_2SO_4. Cover this with a watch crystal coated with melted paraffin and on which the student has drawn a design with a needle or fine pencil point, and warm gently. Leave during lecture hour and note the etching.

[53] Take three small test-tubes and add a few drops of a solution of a chloride to the first, of a bromide to the second, and of an iodide to the third. Add to each 5 drops of $AgNO_3$ solution. Note a pure white precipitate of AgCl in the first, a yellowish white of AgBr in the second, and a yellow of AgI in the third. Add ammonia water to each and note that the AgCl dissolves easily, the AgBr with difficulty, and the AgI remains insoluble.

it less affinity than iodine, chlorine less than bromine, and fluorine so little that it never combines with oxygen at all. Hence the oxysalts of the group are very unstable substances, decomposing easily, and readily giving up their oxygen. So they are much used in chemistry as oxidizing agents,[54] in medicine as disinfectants, and in the combustible and explosive mixtures of pyrotechny, etc.[55]

III. Sulphur Group.

OXYGEN (already described) . . . . O 16
SULPHUR . . . . S 32
SELENIUM . . . . Se 79
TELLURIUM . . . . Te 128

The elements comprising this group are solid at ordinary temperatures ; bivalent and sexivalent ; possess electro-negative affinities which, as in most other groups, decrease as the atomic weights increase ; form hydracids as well as oxacids.

The analogy between their compounds is shown in the following table :

Hydro-ic Acid.	Dioxide.	Trioxide.	Hypo-ous Acid.	-ous Acid.	-ic Acid.
H_2S	SO_2	SO_3	H_2SO_2	H_2SO_3	H_2SO_4.
H_2Se	SeO_2	SeO_3	. . . . .	H_2SeO_3	H_2SeO_4.
H_2Te	TeO_2	TeO_3	. . . . .	H_2TeO_3	H_2TeO_4.

Selenium and Tellurium are of no medical interest, and will not be noticed further.

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[54] Their oxidizing action on combustibles may be shown by : (a) Mix together a drachm each of powdered potassium chlorate and sugar; place on a brick, and touch off with a glass rod dipped in sulphuric acid. A vigorous combustion occurs. (b) Drop some crystals of potassium chlorate into a conical glass of water; add several bits of phosphorus; then by means of a pipette introduce sulphuric acid at the bottom of the glass. The phosphorus takes fire and burns at the expense of the oxygen of the potassium chlorate.

[55] Mix on a sheet of paper 2 grams of powdered potassium chlorate and .5 gram of some combustible powder, as sulphur, antimony sulphide, or tannin. Wrap it up in the paper, place upon an anvil, and strike with a hammer. It explodes violently.

SULPHUR *occurs* free, especially in the neighborhood of volcanoes ; occurs combined as sulphides and sulphates in many valuable ores, and in small quantity in the animal and vegetable kingdoms.

Preparation.—The native sulphur, freed from stones, is refined by distillation, as shown in Fig. 18. The crude sulphur is melted in the tank by the hot draft from the fire below, and then runs down through a pipe into the retort, where it is vaporized. This

FIG. 18.
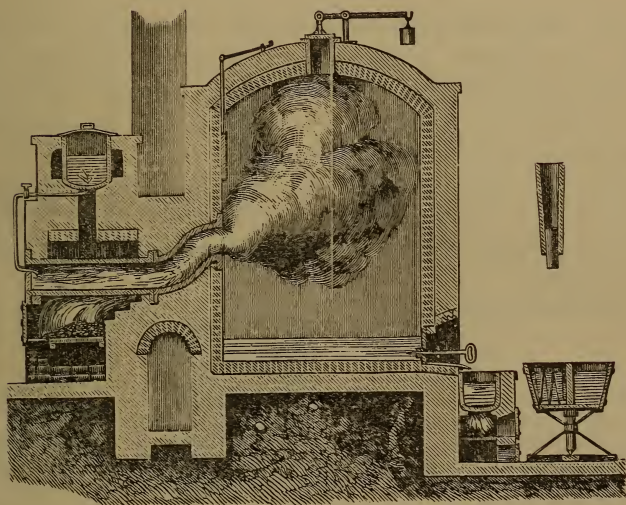
vapor, entering a large brick chamber, is condensed into fine, feathery crystals, called *flowers of sulphur* or *sublimed sulphur*. If the chamber be hot, it condenses into a liquid, which is drawn off and moulded into rolls, called *roll brimstone*. Sublimed sulphur is apt to contain more or less acid, and is washed (*sulphur lotum*). Boiled with lime and precipitated with HCl, it forms *sulphur precipitatum*, U. S. P. This mixed with water is *milk of sulphur* (*lac sulphuris*, U. S. P.).

Physical Properties. A brittle yellow solid ; insoluble in water, hence tasteless ; almost insoluble in alcohol, but very soluble in benzine, chloroform and carbon disulphide. It occurs in four allotropic modifications.[56]

Chemical Properties.—Inflammable, hence called " brimstone " (burn-stone). Combines with metals,[57] forming sulphides.[58] Sulphur forms compounds remarkably analogous to those of oxygen, *e. g.:*—

$$H_2O\ldots\ldots\ldots KHO\ldots\ldots\ldots CO_2\ldots\ldots\ldots H_2CO_3\ldots\ldots\ldots HCNO.$$
$$H_2S\ldots\ldots\ldots KHS\ldots\ldots\ldots CS_2\ldots\ldots\ldots H_2CS_3\ldots\ldots\ldots HCNS.$$
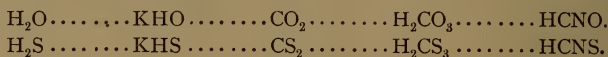
Uses.—In the arts, to make gunpowder, matches, etc. ; in medicine, as a laxative, parasiticide and alterative. We have only theoretical explanations of the method of its absorption ; but that it is absorbed is certain, for persons taking it excrete enough to blacken silver carried on the person.

HYDROGEN SULPHIDE—H_2S—*Hydrosulphuric Acid or Sulphuretted Hydrogen—occurs* in sewer gas and other effluvia from decomposing organic sulphurized matters, and in the water of sulphur springs.

Prepared in laboratory by decomposing a sulphide,[59] thus : —

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

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[56] Melt a tablespoonful of sulphur in a covered porcelain dish or crucible; let it cool and break the crust that forms and pour the still melted sulphur into water. Note (*a*) the *prisms* remaining in the dish as well as (*b*) the *plastic amorphous*sulphur in the water. Dissolve a pinch of sulphur in a few drops of CS_2; allow a drop to evaporate on a slide and examine (*c*) the *rhombic crystals* under the microscope. Boil a little lime and sulphur in water; decant the clear liquid and add HCl. Note the (*d*) amorphous white powder of precipitated sulphur suspended in the liquid (milk of sulphur).

[57] In a small glass flask, a little sulphur is heated to boiling. If now a bundle of fine copper wire or a piece of sodium, in a combustion spoon, be previously heated and then lowered into the vapor, it burns brilliantly.

[58] Mix in a dish equal parts of iron filings and flowers of sulphur.: moisten with water and set aside. Within a half hour it gets hot, vaporizes the water, and is converted into a black mass of FeS.

[59] Into a side-neck test-tube, or better a flask with funnel and delivery tube, Fig. 19, put a few lumps of FeS and dilute H_2SO_4 or HCl enough to cover the FeS. Note the physical and chemical properties of the gas evolved.

Physical Properties.—Colorless gas, having the odor of rotten eggs or intestinal flatus ; slightly soluble in water.

Chemical Properties.—Very feeble acid ; burns[60] with pale blue flame :—

$$H_2S + 3O = SO_2 + H_2O.$$
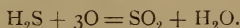
Forms characteristic precipitates with most metallic salts,[61] hence a valuable test reagent.

FIG. 19.
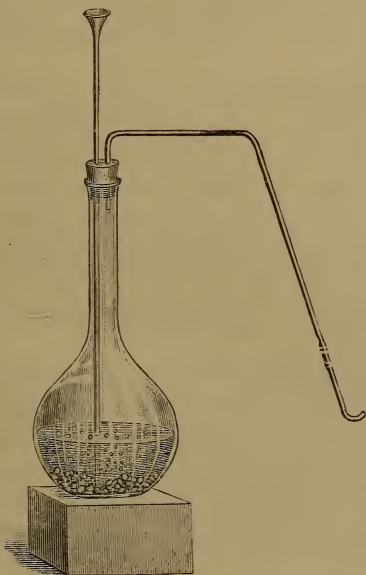
Tests.—The presence of H_2S even in minute quantities may be

[60] Burn the gas from a jet: (*a*) Hold near the flame a glass rod dipped in ammonia; white crystals of ammonium sulphite are formed. (*b*) Hold a cold, dry bell-glass over the flame; it is bedewed with water.

[61] To show the action of H_2S on metallic salts, connect several wash bottles with the generator as shown in Fig. 20. A dilute solution of lead acetate is put in the first, of tartar emetic (antimony) in the second, of arsenic in the third, of zinc sulphate in the fourth. The gas in passing precipitates lead sulphide (black) in the first, antimonious sulphide (orange) in the second, arsenous sulphide (yellow) in the third, zinc sulphide (white) in the fourth.

detected by its odor, and by its blackening paper moistened with a solution of lead acetate.

Fig. 20.
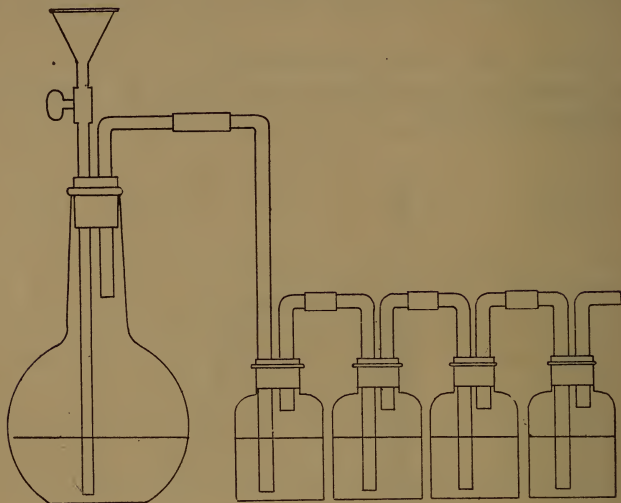
Physiological.—When inhaled, H_2S is an active poison, combining with the hæmgalobulin and destroying its oxygen-carrying power. Even when highly diluted, as in the atmosphere of city dwellings, clumsily "fitted with the modern conveniences," it produces a low febrile condition. When concentrated, or even moderately diluted (one per cent. and over), the gas proves rapidly fatal.

Treatment.—Fresh air, artificial respiration, and stimulation.

CARBON DISULPHIDE—CS_2.—Obtained by bringing S into contact with heated charcoal. A colorless, volatile liquid of a fetid odor, unless it is very pure. A valuable solvent for S, P, india-rubber, etc. Dissolved in water (1–400) a useful antiseptic.

SULPHUR OXIDES AND ACIDS.

Dioxide—$SO_2 + H_2O = H_2SO_3$—Sulphurous acid.
Trioxide—$SO_3 + H_2O = H_2SO_4$—Sulphuric acid.

SULPHUR DIOXIDE, SO_2, *occurs* whenever sulphur or any of its compounds are burned in air or oxygen.

Prepared in laboratory by decomposing and reducing sulphuric acid by copper or charcoal,[62] thus:

$$2H_2SO_4 + Cu = CuSO_4 + 2H_2O + SO_2.$$
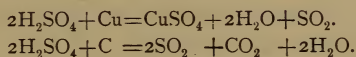$$2H_2SO_4 + C = 2SO_2 + CO_2 + 2H_2O.$$

Physical Properties.—A colorless gas, with a suffocating odor (of burning matches); dissolves in water to form sulphurous acid (H_2SO_3).

Chemical Properties.—Neither burns nor supports combustion; a strong deoxidizer; by removing O from coloring matters and infecting germs it bleaches[63] and disinfects.

Uses.—Sulphur dioxide, sulphurous acid, and the sulphites possess the property of destroying microörganisms and arresting fermentations. A sulphite digested with sulphur forms a so-called hyposulphite, thus:

$$Na_2SO_3 + S = Na_2S_2O_3.$$
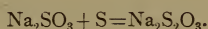
Sodium hyposulphite, more correctly called sodium thiosulphate, has the same uses as the sulphites, and is also a valuable solvent of the silver salts in photography.

SULPHUR TRIOXIDE, SO_3.—Made by oxidizing SO_2 in the manufacture of sulphuric acid. This is done upon a large scale by passing SO_2 from burning sulphur into a chamber kept filled with

---

[62] To make SO_2 and study its properties: (a) burn a sulphur match; (b) warm a mixture of powdered S and H_2SO_4; (c) heat copper wire in strong H_2SO_4; (d) add HCl to sodium sulphite. Note that the gas is colorless and irrespirable, neither burns nor supports combustion, dissolves in water, forming an acid solution (H_2SO_3) that tastes sour and bleaches organic colors.

[63] Some sulphur is ignited beneath a tripod on which fresh flowers are placed, and the whole covered by a bell-glass. The flowers are bleached. The color may be restored by washing with some dilute alkali or acid that will combine with or displace the SO_2, or with very dilute nitric acid, which will restore the oxygen removed by the SO_2.

vapor of nitric acid, steam and air.[64]   The nitric acid gives up a part of its oxygen to oxidize a portion of the SO_2 to SO_3.

$$2HNO_3 + 3SO_2 = 3SO_3 + H_2O + N_2O_2.$$
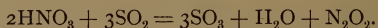
The SO_3 then combines with the water thus produced ($SO_3 + H_2O = H_2SO_4$), and more water is supplied by a jet of steam thrown constantly into the chamber.

The N_2O_2 has the power of taking up oxygen from the air and becoming N_2O_4,

$$N_2O_2 + O_2 = N_2O_4,$$

which in turn parts with this oxygen to oxidize a new quantity of SO_2,

$$N_2O_4 + 2SO_2 = N_2O_2 + 2SO_3.$$

Thus the process is kept up as long as the SO_2, air, steam, and N_2O_2 are supplied.   The acid condenses with the water upon the floor of the chamber, and is drawn off, concentrated, and sold as

SULPHURIC ACID—H_2SO_4—"*Oil of Vitriol.*" [65]

Physical Properties.—A dense, colorless, oily-looking liquid, without odor.[66]

Chemical Properties.—Strong acid; very avid of water, not only dissolving in it, but combining with it, the act evolving considerable heat;[67] chars organic matters by abstracting H and O to form water.[68]

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[64] The manufacture of sulphuric acid may be illustrated on the lecture table by the apparatus shown in Fig. 21.   The lead chamber is represented by a large flask.   Into this are led (*a*) N_2O_2 from the flask on the right; (*b*) SO_2 from a mixture of sulphur and manganese dioxide in the flask in the rear; (*c*) steam from the other flask, and (*d*) air or oxygen through the open tubes.

[65] To make H_2SO_4 in small test-tubes.   (*a*) Boil a little powdered sulphur and strong HNO_3; (*b*) carefully heat a pinch of sulphur with a few crystals of $KClO_3$ till it ignites; test for H_2SO_4 by means of $BaCl_2$ solution.

[66] Take a reagent bottle of strong H_2SO_4 and note its appearance, weight, taste, etc.

[67] To about 5 Cc. of it in a test-tube add an equal bulk of water and note heat produced.

[68] Moisten a bit of match, paper, cloth or other organic substance, with the acid and note that it is charred, even the dilute acid doing so if it is warmed; and for this reason be careful not to spill any on the table or your clothes.

Tests.—(1) The concentrated acid, if placed on a piece of paper or other organic material, will char it.[69] If dilute, it will char the paper only after being warmed and concentrated by the

FIG. 21.
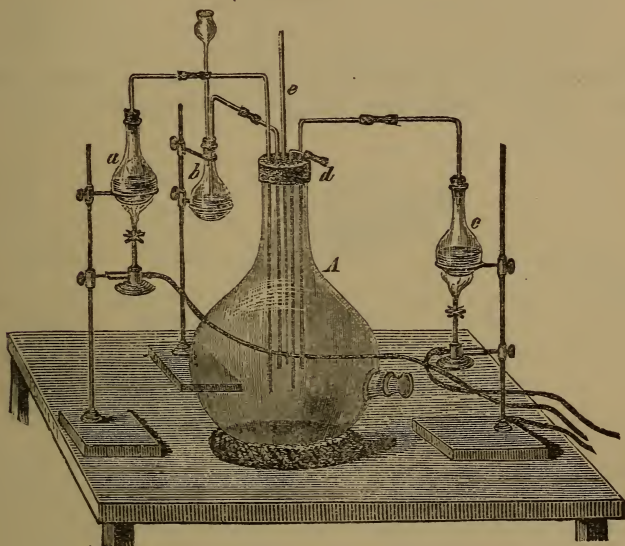
evaporation of its water. (2) Sulphuric acid, or any other sulphate, will form with a solution of a barium salt a white precipitate ($BaSO_4$) insoluble in nitric or hydrochloric acid.[70]

Uses.—So important in the arts that the commercial prosperity of a country may be measured by the amount of H_2SO_4 consumed. Properly diluted, it is a refrigerant tonic, but concentrated it is a severe caustic.

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[69] Pour some strong H_2SO_4 on an equal quantity of sugar or strong syrup; note that a mass of charcoal is formed.

[70] To 5 Cc. of water in a test-tube add a few drops of some sulphate and then a few drops of $BaCl_2$. Note white precipitate. Agitate and pour half into another tube. Add HCl to the first tube and HNO_3 to second, and note that the precipitate ($BaSO_4$) is not dissolved.

IV. Nitrogen Group.

NITROGEN, ... N 14
PHOSPHORUS,................. .... P 31
ARSENIC, ... As.................. 75
ANTIMONY (Stibium), ... Sb.................. 120
BISMUTH, ... ·.·. Bi 208

Trivalent and Quinquivalent. This group, as shown below, forms a graded series from nitrogen at the negative, to bismuth at the positive end :—

N	P	As	Sb ·	Bi
14	31	75	120	208
	Sp. gr. 1.83.	Sp. gr. 5.67.	Sp. gr. 6.7.	Sp. gr. 9.8.
Gas, with full negative tendencies.	A soft solid.	Solid.	Dense solid.	Very dense solid.
	Easily volatilizable.	Volatilizable.	Difficultly volatilizable.	Non-volatilizable.
	Destitute of metallic lustre.	Some metallic lustre.	Great metallic lustre.	Full metallic lustre.
	Negative tendencies.	Both negative and positive tendencies.	More positive tendencies.	Full positive tendencies.

The following will exhibit the relations of some of the most important compounds :—

Hydrides.	Chlorides.		Oxides.		Sulphides.	
	-ous.	-ic.	-ous.	-ic.	-ous.	-ic.
NH_3	NCl_3,	....	N_2O_3,	N_2O_5	....	....
PH_3	PCl_3,	PCl_5	P_2O_3,	P_2O_5	P_2S_3,	P_2S_5
AsH_3	$AsCl_3$,	$AsCl_5$	As_2O_3,	As_2O_5	As_2S_3,	As_2S_5
SbH_3	$SbCl_3$,	$SbCl_5$	Sb_2O_3,	Sb_2O_5	Sb_2S_3,	Sb_2S_5
....	$BiCl_3$,	....	Bi_2O_3,	Bi_2O_5	Bi_2S_3	....

Vanadium, Columbium and *Tantalum* belong to this group, but are rare metals and as yet of little importance.

NITROGEN *occurs* uncombined in the atmosphere ; combined in some mineral, and all vegetable and animal bodies, especially in the more highly organized tissues.

Prepared most easily by burning phosphorus in a confined

space until the oxygen is removed from the air.[71] Prepared in this way it contains small quantities of other gases found in air. To prepare it pure, heat ammonium nitrite ($NH_4NO_2 = 2H_2O + N_2$).

Physical Properties.—A colorless, tasteless, odorless gas, a little lighter than air.

Chemical Properties.—Little tendency to combine with other elements, and its compounds, once formed, are very prone to

FIG. 22.
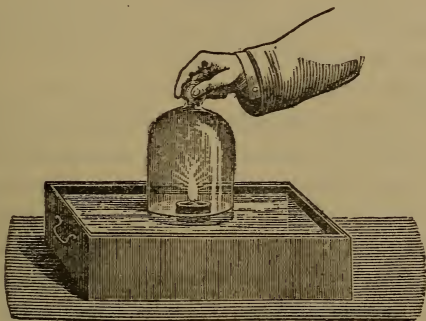
decompose, either with violent decomposition[72] or gradual putrefaction; neither combustible nor a supporter of combustion; negatively poisonous.

THE ATMOSPHERE. Air, considered by the ancients one of the four elements (fire, earth, air and water), is neither an element nor a compound. It is a mixture,[73] mainly of nitrogen and

[71] A flat piece of cork floating on water supports a capsule containing a bit of phosphorus carefully dried. This is ignited and immediately covered with a bell jar. The jar is filled with a dense white cloud from the combustion, which ceases only when the oxygen is all consumed. At first the air expands, and some may be forced out. Upon cooling, the water rises to take the place of the oxygen, the white fumes gradually dissolve in the water, and the nitrogen is left clear and comparatively pure, Fig. 22.

[72] To tincture of iodine add excess of ammonia water. Filter to separate the precipitated iodide of nitrogen. Put portions of this on separate bits of paper and set aside. When dry they explode on the slightest touch.

[73] Proofs that air is a mixture: (1) Its constituents are not in atomic pro-

oxygen, the function of the former being to dilute the latter. Miller gives the average composition of air as follows:

	Volumes.
Nitrogen	77.95
Oxygen	20.61
Carbon dioxide	.03
Aqueous vapor	1.40

Also traces of nitric acid, ammonia, sodium chloride, ozone, dust, bacteria, germs, etc. In the neighborhood of large cities various other substances are poured into the air from manufactories. Yet, owing to the rapid diffusion of gases, the composition of the air is almost the same everywhere.

Watery Vapor. The higher the temperature the more water air will hold. A warm, dry, air, when cooled, will appear damp, and the temperature at which it begins to deposit its water is its *dew point.* A cold, damp air, when heated, becomes capable of holding more water, and appears dry, hence the necessity of supplying water to the heated air of our rooms in winter, especially in cases of bronchitis or catarrhal croup. Even in health, a very dry air irritates the air passages, produces dryness of the skin and *malaise;* while a very moist atmosphere retards evaporation from the skin and lungs, raises the body temperature and becomes oppressive.

Suspended Matters in air are of a great variety of substances. The irritation of dust incident to certain trades may cause chronic bronchitis, emphysema and phthisis. Germs floating in the air are believed to be the cause of many contagious, infectious, and malarial diseases. The best disinfectants[74] are (*a*) free ventila-

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portions; (2) air can be made by mechanically mixing the gases; (3) solvents may remove one gas without affecting the others, each dissolving according to its own solubility.

[74] *Disinfectants* destroy the power to infect, whether it be due to germs or other agents.
Germicides destroy germs.
Antiseptics prevent putrefaction.
Antizymotics prevent fermentation.
Deodorizers destroy offensive odors.

tion and consequent dilution; (*b*) chlorine, bromine, iodine and formaldehyde, sulphur dioxide and formaldehyde.

ARGON, HELIUM, &c. *Argon* was discovered in 1894 by Lord Rayleigh and Prof. Ramsay, as a residue (1 per cent.) after removing all the oxygen, nitrogen, etc., from air. A colorless, odorless gas that out-nitrogens nitrogen in its lack of affinity. *Helium*, (ἥλιος, the sun) has, from its line in the solar spectrum, long been known to exist in the sun's atmosphere, but was not discovered till 1895, when Ramsay obtained it from certain minerals. *Krypton* and *Neon* are two new elements Ramsay and Travers claim to have recently discovered.

AMMONIA, NH₃.—Occurs in the effluvia from decomposing nitrogenized organic bodies; for nitrogen, and hydrogen will not combine except in the nascent state (see page 33). First obtained from the destructive distillation of camels' dung near the temple of Jupiter-Ammon in Libya; hence called "ammonia." Later it was obtained by heating clippings of hides, hoofs and horns,[75] especially of deer (the hart) in closed iron retorts, and was called "spirit of hartshorn." Coal contains about two per cent. of nitrogen, a part of which in the manufacture (destructive distillation) of coal-gas comes off as ammonia. In washing the coal-gas the ammonia dissolves, and this solution is now its commercial source.

Preparation.—Ammonia may be prepared in various ways, as above suggested. In the laboratory it is usually obtained by driving it off from the commercial "aqua ammoniæ" by heat.

Physical Properties.—Transparent, colorless gas of an irritating odor; condenses under a pressure of about 100 pounds to square inch (6 or 7 atmospheres) at ordinary temperatures, into a color-

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[75] Mix some Ca2HO, KHO or NaHO with some nitrogenized organic substance, as albumin, wool or, best of all, and easily obtainable and agreeable, chipped dried-beef. Heat in a test-tube. Ammonia gas is evolved, recognized by its odor, alkalinity, or by white fumes when a glass rod is thrust into the mouth of the tube.

less liquid.[76] Ammonia is exceedingly soluble, water dissolving from 500 to 1000 times its own volume.[77]

Chemical Properties.—Ammonia is not ordinarily combustible, though it may be made to burn if mixed with a small amount of oxygen. It is alkaline in solution, and combines with acids to
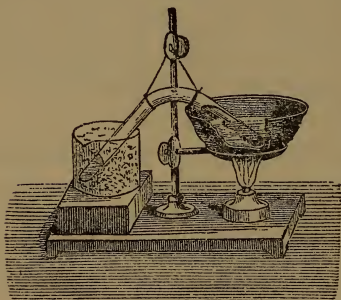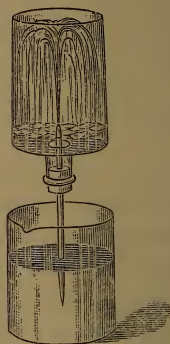

FIG. 23.

FIG. 24.

form the well-known ammonium salts which will be considered in another group.

Uses.—Ammonia, liquefied in iron drums strong enough to resist the pressure, is sold in large quantities for ice-making. Water of ammonia is largely employed in chemistry, pharmacy and medicine, the gas from it being often administered in syncope, chloroform narcosis, etc., but care must be taken lest its too

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[76] Make ammonium-silver chloride by passing ammonia gas over silver chloride. Seal this in a bent glass tube (Fig. 23). The end containing the compound is heated in a water-bath, while the other is cooled in an ice mixture. Ammonia gas is driven off from the compound, and condenses into a colorless liquid in the cold end of the tube.

[77] The absorption of ammonia gas by water may be illustrated by filling a large bottle with the gas by upward displacement, and closing the mouth with a rubber cork through which passes a glass tube sealed at its outer end. If this sealed end be plunged under water and broken off, the water rushes in forming a beautiful fountain (Fig. 24). If the water be colored red with litmus, it will become blue as it enters the bottle, showing that the water has become alkaline.

liberal use on the unconscious patient cause spasm of the glottis or set up a dangerous bronchitis.

Tests.—The gas may be recognized by (*a*) its smell, (*b*) white fumes with HCl, (*c*) turning moistened red litmus blue. Its compounds must be warmed with a strong alkali[78] to liberate the ammonia gas, which can then be recognized as just described. A most delicate test is Nessler's Reagent,[79] which gives a yellowish brown with ammonia or its compounds.

FIG. 25.
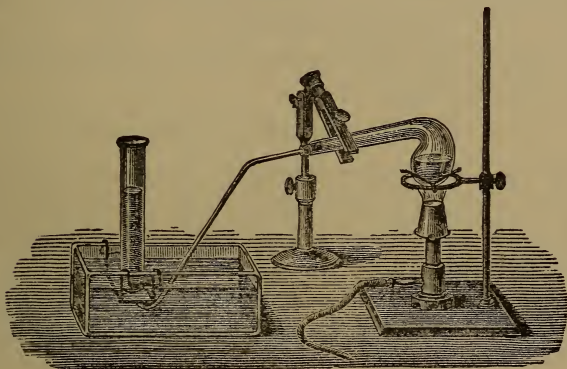
NITROGEN OXIDES.

Monoxide—$N_2O + H_2O = 2HNO =$ Hyponitrous acid.
Dioxide—N_2O_2. No corresponding acid.
Trioxide—$N_2O_3 + H_2O = 2HNO_2 =$ Nitrous acid.
Tetroxide—N_2O_4. No corresponding acid.
Pentoxide—$N_2O_5 + H_2O = 2HNO_3 =$ Nitric acid.

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[78] Mix lime with NH_4Cl and heat in a test-tube. Test the NH_3 as above described, and expose to it a paper moistened with $CuSO_4$ solution, and note the deep blue ammonio-sulphate of copper formed.

[79] *Nessler's Reagent.* Dissolve 35 gm. of KI in 100 Cc. of water and 17 gm. of $HgCl_2$ in 300 Cc. of water; add the first to the second until the precipitate first formed is *almost* re-dissolved. Then add 20 per cent. NaHO solution, enough to make one liter.

NITROGEN MONOXIDE—N_2O (*Nitrous Oxide—Laughing Gas*). —*Prepared* by heating ammonium nitrate,[80] as shown in Fig. 25.

$$NH_4NO_3 = N_2O + 2H_2O.$$
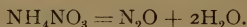
Physical Properties.—Colorless, odorless gas, of sweetish taste. Dentists keep it liquefied under pressure in iron cylinders.

Chemical Properties.—By the ease with which it gives up its O it is a supporter of combustion and life, next to O itself.

Medical.—Inhaled, diluted with air, it produces exhilaration of spirits, muscular activity, and then complete anæsthesia. Used in dental and other brief minor operations.

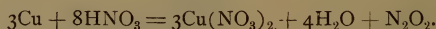NITROGEN DIOXIDE—N_2O_2 (*Nitric Oxide*).—*Prepared* by action of nitric acid on copper :—[81]

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 4H_2O + N_2O_2.$$

A colorless gas, which, when coming in contact with free O, forms red vapors of N_2O_3 and N_2O_4 ; hence a test for free O. Unlike N_2O, it is not a supporter of combustion, except to substances very avid of oxygen.[82]

NITROGEN TRIOXIDE—N_2O_3 AND NITROUS ACID—HNO_2.—Nitrous acid is known only in its salts, the nitrites. These are produced in nature by the oxidation of nitrogenous organic matter in the presence of certain forms of microscopic life.

This nitrification occurs in waters polluted with organic matter,

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[80] Put 5 Cc. of NH_4NO_3 in a side-neck test-tube with cork and delivery-tube (Fig. 8). Collect gas over warm water; note that glowing match-stick bursts into flame when thrust in.

[81] Copper turnings, clippings, or wires are placed in a flask, and nitric acid diluted with half its volume of water is poured in, and the flask set in cold water. Red fumes soon fill the flask, but when these have escaped the gas appears colorless, turning red, however, on reaching the air. The colorless gas is collected over water.

[82] The student might use the apparatus shown in Fig. 7, but must be exceedingly careful not to inhale the fumes. Collect two cylinders of N_2O_2: (*a*) Into one introduce burning phosphorus; it burns with great brilliancy. (*b*) To the other add a few drops of CS_2 and agitate to mix the vapor and gas; then ignite with a flame, and note the blinding, bluish-white blaze, remarkably rich in chemical rays.

and normally in the soil, where the acid so formed combines with
bases. Hence, nitrites in water is evidence of previous contami-
nation with nitrogenous matter. Further oxidation forms nitrates.

NITROGEN TETROXIDE—N_2O_4—*occurs* in company with N_2O_3 in
the brown fumes given off whenever nitric acid is decomposed, as
in certain laboratory and manufacturing processes.[83] *The effect* of
breathing air thus contaminated is to produce chronic inflamma-
tion of the respiratory tract. If the vapor be more concentrated
the effects are more acute and serious. At first there is only a
cough, in two or three hours a difficulty in breathing, and in about
twelve hours, death. The remedy is ventilation.

NITROGEN PENTOXIDE—N_2O_5—is of no medical interest.

NITRIC ACID—HNO_3 (*Aqua Fortis*)—*occurs* in traces in the
atmosphere and as nitrates in the soil. (See Nitrites.)

FIG. 26.
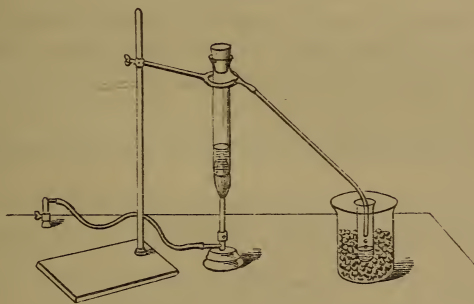
Prepared by distilling a nitrate with sulphuric acid.[84]

$$2KNO_3 + H_2SO_4 = K_2SO_4 + 2HNO_3.[85]$$
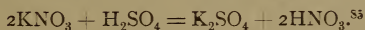
[83] In a side-neck test-tube (Fig. 26) strongly heat some dry Pb $2NO_3$ and
condense the fumes in a test-tube in a freezing mixture of ice and salt.

[84] In the laboratory nitric acid may be prepared with the apparatus shown in
Fig. 15. Equal parts of sodium nitrate and sulphuric acid are heated in the
retort A. The nitric acid produced is vaporized by the heat and recondensed
in the tube B kept cool by an outer tube C, through which flows a stream of
water from an elevated vessel. The acid is collected in the vessel D.

[85] The student had better use the apparatus shown in Fig. 26.

Physical Properties.—Heavy liquid and colorless, but if old and exposed to light it becomes yellow or orange from presence of N_2O_2 and N_2O_4. Like all nitrates, it is soluble in water.

Chemical Properties.—HNO_3 readily gives up a portion of its oxygen, and hence is an energetic oxidizer. Many organic substances, as cotton, glycerine, etc., undergo in contact with HNO_3 a process of *nitration* in which the radical NO_2 is substituted for H, and they (gun-cotton, nitroglycerine, etc.) are much more unstable, combustible, and even explosive. HNO_3 coagulates albumin and stains albuminoid bodies a permanent yellow.[86]

Medical Properties.—The officinal nitric acid contains 68 per cent, and the dilute 10 per cent of HNO_3. The strong acid is a a powerful escharotic, but the dilute is a valuable digestive tonic.

PHOSPHORUS (light-bearer). *Occurs,* combined with oxygen, in the ancient, unstratified rocks. These disintegrate and form soil, from which the phosphorus passes into the organisms of plants, and thence into the bodies of animals, being present in every tissue, but mainly stored up in the skeleton. First isolated by Brandt in 1669 from urine, but now obtained exclusively from bones.

Physical Properties.—A soft, yellow, solid, resembling unbleached wax.[87]

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[86] Of the acid formed in the preceding experiment:

(*a*) Put a drop on white of egg or fresh meat, and note that the albumen is coagulated.

(*b*) Place a drop on some dry albuminoid substance, as skin, hair, wool, etc., and note the yellow stain, not discharged by alkalies.

(*c*) Moisten a bit of paper or cloth with the acid and dry gently; note that it burns like tinder.

(*d*) Add a few drops to a solution of indigo or other organic dye, and note the oxidizing and bleaching effect.

(*e*) To some turpentine warmed in a test-tube, add the strong acid; it inflames.

(*f*) Lay a drop on clean copper or tin, and note the red fumes.

(*g*) Mix in a test tube equal volumes of H_2SO_4 and an aqueous solution of $FeSO_4$, and when cool, add HNO_3 or any other nitrate; note a brown coloration, disappearing on heating or even shaking.

[87] When heated to 500° F. in an atmosphere incapable of acting upon it, phosphorus is converted into a reddish-brown powder, which, unlike ordinary phosphorus, is not poisonous, not inflammable, and insoluble in the ordinary solvents.

Chemical Properties.—Very inflammable,[88] so kept under water ; exposed to the air, it undergoes a slow combustion, emits the odor of ozone, and is luminous in the dark.

Physiological.—Liable to inflame from careless handling, and burns by it are difficult to heal. In medicinal doses, a nerve tonic and aphrodisiac ; in larger quantities a virulent poison and gastro-irritant. Sometimes given with homicidal intent, but more frequently taken accidentially as rat poison, tips of matches, etc. Workmen in match factories suffer from irritation of stomach and bowels, caries of teeth, necrosis of bones, especially of lower jaw, and from fatty degeneration of various organs. This may be prevented by using the red allotropic variety, which is harmless.

No good antidote. Evacuate the stomach ; give copper sulphate[89] as emetic and antidote ; give old turpentine, the ozone of which oxidizes the P. Avoid fats, for they dissolve it.

Tests.—(1) Shines in the dark ; (2) emits garlicky odor.

PHOSPHINE—PH_3 (*Phosphoretted Hydrogen.*)—*Occurs* mixed with other hydrides of P in the gases arising from decomposing animal or vegetable matters, especially under water ; hence seen as the *ignis fatuus*, or "Will-o'-the-wisp," over marshes and graveyards.

Prepared by boiling phosphorus in a solution of caustic potash.[90]

Properties.—Colorless gas of a garlicky odor ; inflames spontaneously upon coming in contact with the air ; very poisonous,

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[88] Dissolve some phosphorus in carbon disulphide. Pour this on a sheet of filter paper hung on a retort stand. Soon the solvent evaporates and leaves the phosphorus in such a fine state of division that it inflames spontaneously.

[89] Place a clean bit of phosphorus for a minute in a solution of copper sulphate. Remove, and note the coating of metallic copper.

[90] Into a retort, whose delivery tube dips under water in a dish (Fig. 27), add liquor potassæ and a few bits of phosphorus. Expel the air by passing hydrogen or illuminating gas through the retort, or by adding a few drops of ether, the vapor of which does the same thing. On applying heat the hydrogen or illuminating gas or ether vapor first escapes, then come bubbles of PH., each of which, as it bursts into the air, ignites spontaneously, forming beautiful rings of white smoke rotating on their circular axes. These may ascend to the ceiling if the air be still.

destroying the oxygen-carrying power of the blood, which after death is found to be dark-colored, with a violet tinge.

FIG. 27.
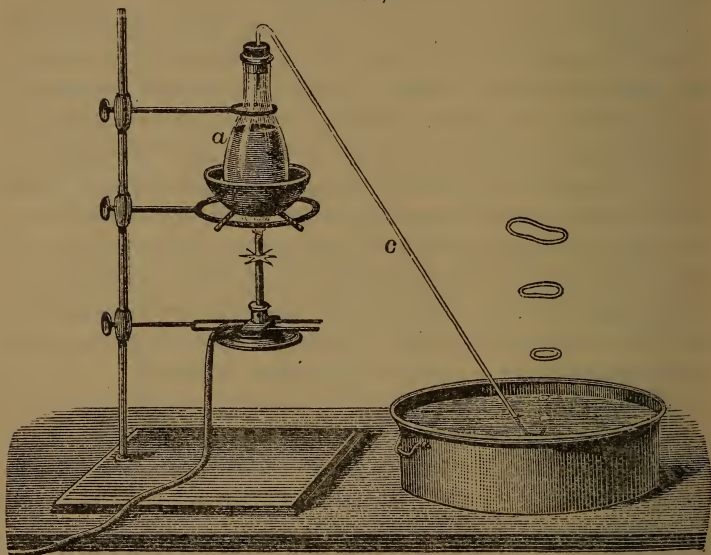
OXIDES AND OXACIDS OF PHOSPHORUS.—These are analogous to those of nitrogen, except that several members are missing and that the oxides, in combining with water to form their respective acids, may take three or two or one molecule of H_2O, and each oxide thus form three different acids, distinguished by the prefixes, "ortho-," "pyro-" and "meta-;" for example :—

$$\begin{array}{ll} P_2O_5 & \left\{ \begin{array}{l} + 3H_2O = H_3P_2O_8 = 2H_3PO_4 = \text{Orthophosphoric acid.} \\ + 2H_2O = H_4P_2O_7 = \text{Pyrophosphoric acid.[92]} \\ + H_2O = H_2P_2O_6 = 2HPO_3 = \text{Metaphosphoric acid.} \end{array} \right. \end{array}$$

Phosphorus Pentoxide.[91]
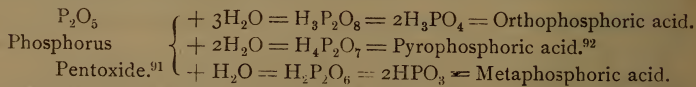
[91] A little stand in the middle of a dinner plate supports a capsule in which is put a bit of phosphorus freed from adhering water. This is ignited and covered with a bell-jar. The jar is filled with clouds of P_2O_5, which, aggregating, fall into the plate like a minature snow storm.

[92] Place a few crystals of Na_2HPO_4 in a dish and heat till it melts and loses a part of its water; dissolve the residue ($Na_4P_2O_7$) in water and test with $AgNO_3$ solution; note the white precipitate of $Ag_4P_2O_7$.

The " ortho- " acids and salts are the ones so generally used that when the " pyro- " and " meta- " are not specified, the " ortho- " are meant.

HYPOPHOSPHOROUS ACID.—This acid is seldom prescribed, but the *hypophosphites* in powder, or better in pill or syrup, are much employed, especially in anæmia, tuberculosis, etc. It should be remembered in prescribing, especially with reducible metallic salts, that the hypophosphites are deficient in oxygen and strong reducing agents.

PHOSPHOROUS ACID and the PHOSPHITES are seldom prescribed in medicine and of but little importance ; prone to oxidize into phosphoric acid and phosphates.

ORTHOPHOSPHORIC ACID.— Never found free, but is widely distributed in its salts, the phosphates, in the tissues of plants and animals, especially in bones, and in the earth, the " phosphate-beds " of our southern sea-coast being its principal source. The officinal acid is, or should be, made from phosphorus and nitric acid. Being the phosphoric acid most used in medicine (the other two are poisonous) it is usually called simply " phosphoric acid." A transparent, sour, syrupy liquid ; but when free from water and cold it is in rhombic crystals, the so-called glacial phosphoric acid. Heated above 200° C. (392° F.) it is converted into pyrophosphoric and metaphosphoric acid.

Phosphoric acid does not coagulate albumin, and in the diluted form is much used as a digestive tonic.

Its usual *tests* are, (*a*) with $AgNO_3$, a yellow precipitate soluble in nitric acid and ammonia ; (*b*) with the magnesian fluid of the U. S. P., a white precipitate soluble in acids.[93]

ARSENIC.—Arsenic (*arsenum*) occurs mostly as sulphide, usually associated with other metals. The ore is roasted, and the resulting oxide heated with carbon (charcoal) yields the metal. This is a brittle, steel-gray crystalline, solid possessing a marked metallic lustre. Heated out of contact with air it sublimes ; in

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[93] Boil some match-heads in a test-tube with dilute nitric acid; neutralize with ammonia and test this solution as indicated above for H_3PO_4.
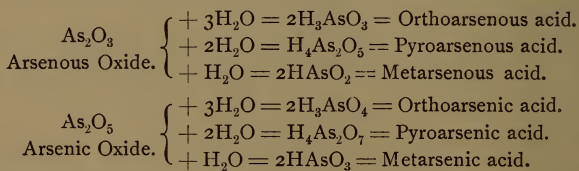
air it burns with a bluish-white flame emitting the odor of garlic and white clouds of As_2O_3. It combines with many elements, its compounds with metals (arsenides) resembling alloys. Used in pyrotechny, the manufacture of shot, pigment and fly-poison. All its compounds are poisonous.

HYDROGEN ARSENIDE—AsH_3—*Arsine*—is of great practical interest to the toxicologist, as its formation constitutes one of the best and most delicate tests for arsenic, for it is formed wherever arsenic finds itself in the presence of nascent hydrogen, *i. e.*, whenever hydrogen is generated in the presence of an arsenical compound. It is so extremely poisonous that chemists (*e. g.*, Gehlen, in 1815) have lost their lives by inhaling it accidentally.

ARSENOUS IODIDE—AsI_3—Prepared by fusing together atomic proportions of its constituent elements. The official "Donovan's Solution" (*liq. arseni et hydrargyri iodidi*) contains 1 per cent. each of AsI_3 and HgI_2, and is considered the strongest alterative in the materia medica.

ARSENOUS SULPHIDE—As_2S_3—occurs native as orpiment; prepared by precipitating an arsenous compound with H_2S; a bright yellow powder, insoluble in water and acid solutions, but soluble in alkaline. Another sulphide is realgar, As_2S_2. Both are used as pigments—orpiment as a yellow and realgar as a red.

OXIDES AND OXACIDS.—These are analogous to those of phosphorus, and like them form ortho-, pyro- and meta- acids.

$$\begin{array}{l} As_2O_3 \\ \text{Arsenous Oxide.} \end{array} \left\{ \begin{array}{l} + 3H_2O = 2H_3AsO_3 = \text{Orthoarsenous acid.} \\ + 2H_2O = H_4As_2O_5 = \text{Pyroarsenous acid.} \\ + H_2O = 2HAsO_2 = \text{Metarsenous acid.} \end{array} \right.$$

$$\begin{array}{l} As_2O_5 \\ \text{Arsenic Oxide.} \end{array} \left\{ \begin{array}{l} + 3H_2O = 2H_3AsO_4 = \text{Orthoarsenic acid.} \\ + 2H_2O = H_4As_2O_7 = \text{Pyroarsenic acid.} \\ + H_2O = 2HAsO_3 = \text{Metarsenic acid.} \end{array} \right.$$

ARSENOUS OXIDE—As_2O_3. *Arsenic, White Arsenic, Ratsbane, Arsenous Acid.*—This is not only the most important compound of arsenic, but the most important of toxic agents, whether we consider the deadliness of its effect or the fatal frequency of its administration. When recently made it is in glassy lumps, which

on exposure become crystalline and opaque. When sublimed it is deposited again in brilliant octahedral crystals. It is odorless, almost tasteless—slightly sweetish. When powdered arsenic is thrown upon water it does not all sink, notwithstanding its heaviness, but floats, showing a repulsion of the water. Very slightly soluble in water; even boiling water dissolves less than two per cent. If the water be made acid or alkaline, it dissolves more readily. When arsenic dissolves in water it forms *arsenous acid*, H_3AsO_3.

There are two officinal solutions, each containing one per cent. of arsenic: (1) *Liq. acidi arsenosi*, in which the water is acidulated with HCl; (2) *Fowler's Solution, liq. potassii arsenitis*, in which the water is made alkaline by K_2CO_3.

ARSENIC OXIDE.—*Arsenic pentoxide* is made when arsenous oxide (As_2O_3) is treated with an oxidizing agent, as nitric acid. It is quite soluble in water, with which it forms a series of *arsenic acids* (ortho-, pyro- and meta-) analogous to the phosphoric acids.

Toxicology of Arsenic.—The deadly effect of arsenical compounds has been known from remote antiquity, and they have probably been more used for homicidal purposes than all other toxic agents combined. Although chemistry has made its detection easy and certain, arsenic is so cheap, so readily administered

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WHITE ARSENIC (*Dry*).

[94] Inspect the powder first with the naked eye and note its color, crystalline form, etc.

[95] Toss a little on water and note that it does not dissolve but floats, though a few larger grains may sink.

[96] Heat a grain on a knife blade; it volatilizes with a white smoke and leaves no residue. Take care not to inhale the fumes.

[97] Take a five-inch piece of small glass tubing and melt it into two portions. Into the open end of one, drop a minute grain and heat; the arsenic sublimes, leaving no residue at the bottom of the tube, but gathering in a ring of octahedral crystals (Fig. 28) around the tube in its cooler portion.

[98] Into the other tube put some arsenic, as above, and also powdered charcoal a quarter-inch deep; hold the tube in the flame so as to heat the charcoal first and then the As_2O_3 as it sublimes will give up its oxygen to the charcoal (reduction) and be deposited above the charcoal in a lustrous, bright ring of metallic arsenic (Fig. 29).

to the unsuspecting victim, and so deadly, that it is still a favorite with the murderer. Owing to the extensive use of arsenical compounds as insect-powders (Paris green, etc.), and as pigments for wall-paper, toys, confectionery, etc., cases of accidental poisoning are quite common.

Few physicians have the training and facilities to undertake an extended analysis, but they should all know the simpler tests, so as to promptly recognize the nature of the poison and combat it intelligently and successfully. Besides, the physician, being early in the case, can by wise precautions prevent breaks in the chain of evidence ; protecting the prisoner if innocent, and closing loopholes of escape if guilty. If foul play is suspected, he should commit all his observations to writing, for notes to be admitted as evidence must be the original ones taken at the time. Having collected the urine, fæces, vomit, and the suspected vehicle of the

WHITE ARSENIC (*in Aqueous Solution*). Boil white arsenic (1 Cc.) in a small flask or large test-tube and submit successive portions of about 5 Cc. each, to the following tests :—

[99] *Hydrogen Sulphide Test.* Pass bubbles of H_2S (see page 47) and note the yellow precipitate of As_2S_3.

[100] *Ammonio-Silver Nitrate Test.* Add cautiously ammonia water to $AgNO_3$ solution until the brownish precipitate first formed is *almost* all dissolved, avoiding excess of ammonia. Add a few drops of this solution to the arsenic water, and note yellow precipitate of Ag_3AsO_3.

[101] *Ammonio-Copper Sulphate Test.* Add ammonia water to $CuSO_4$ solution till bluish precipitate first formed is *almost* dissolved; add a few drops to the arsenic water and note the green precipitate of $CuHAsO_3$ (Scheele's green).

[102] Repeat these three tests on much more dilute solutions of arsenic, and note their extreme delicacy, but take care to avoid excess of the alkali which would hold up the precipitate or redissolve it.

ARSENICAL MIXTURES. The foregoing tests are applicable to pure arsenic or simple solutions, and not to suspected food, stomach-contents, etc. Extemporize a " suspected specimen " by poisoning some coffee with " Rough on Rats " or other common form of arsenic, and test portions as follows :—

[103] *Plating Test* (Reinsch's). Acidulate 5 Cc. of the suspected solution with 1 Cc. of HCl; add a strip of clean arsenic-free copper (such copper foil is sold) and boil ten minutes; note the gray deposit of arsenic on the copper. To prove it is arsenic, remove the copper and wash and dry it, handling and warming it very gently to avoid removing the plating, and then heat in a clean, dry test-tube. Note a sublimate of As_2O_3, which in turn may be dissolved off by boiling water in the tube, and when cool submitted to the other tests.

poison, and having tested some or all of them to verify his suspicion, he should place them under seal or lock and key. He should carefully reserve his opinion, lest he do injustice to the innocent or warn the guilty. In case of death, the coroner should be notified and an autopsy held in the presence of the chemist if possible. The stomach and entire intestinal canal, ligated at both ends, half of the liver, the whole brain, spleen, one kidney, and any urine remaining in the bladder should be saved. These, if possible, should be preserved in separate jars, to which a little pure chloroform may be added to prevent decomposition. These jars must be new and clean, closed with new corks or glass—not zinc caps. They are then to be labeled, and also sealed and stamped, so they cannot be opened without detection, and as soon as possible turned over to the chemist or prosecuting officer.

The symptoms of arsenical poisoning are those common to all intense irritants, viz., nausea, vomiting, burning pain in the epi-

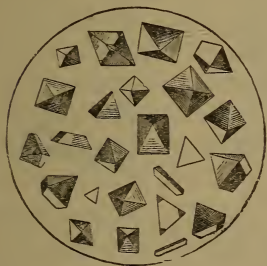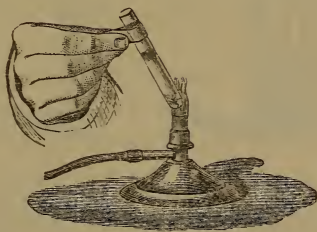FIG. 28.   FIG. 29.

gastrium, purging, cramps, thirst, fever, rapid pulse, etc., ending in collapse. Smallest fatal dose is two grains, and death usually occurs in twenty-four hours.

Treatment.—Remove any unabsorbed poison from the stomach by emetics or stomach-pump. The best *antidote* [104] is freshly pre-

[104] *Antidote—Demonstration.*—Pour into a beaker an inch of $FeCl_3$ solution, add ammonia water until alkaline, strain the precipitate of Fe_3HO on a cloth and wash till clear of ammonia, and then stir fresh precipitate into another beaker containing an inch of arsenic water. After five minutes, filter the mixture and show by the foregoing tests that the filtrate is free of arsenic.

cipitated ferric hydrate, made by adding aqua ammoniæ to a solution of a ferric salt. "Dialyzed iron," being a solution of ferric hydrate, may be used. It should be given at frequent intervals and in tablespoonful doses.

Tests for Arsenic.—The ordinary tests for arsenic are given in the laboratory notes below. The student should practice until he can perform them with readiness and accuracy.

The Hydrogen (Marsh's) Test depends on the fact that AsH$_3$ is always formed whenever hydrogen is generated in the presence of any arsenical compound. Generate hydrogen (Fig. 30) in the

FIG. 30.
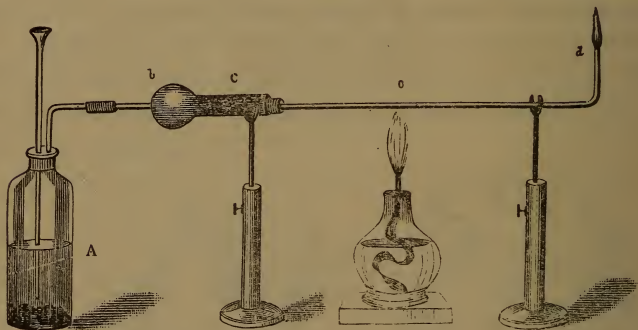
usual way (Zn + H$_2$SO$_4$), and if the chemicals are pure (free from arsenic), the gas burns with a pale yellowish flame, without odor, and does not stain a porcelain dish held in the flame. Then pour into the generator some of the suspected solution. If arsenic be present, there is an odor of garlic; the flame becomes bluish-white, and a cold porcelain dish held in the jet (Fig. 31) so chills the flame that only the H burns, and the As is deposited on the porcelain as a brilliant metallic film. If the delivery tube be heated (Fig. 32), the passing AsH$_3$ is decomposed, and metallic arsenic is deposited farther out in the tube in a film of the the same character as that on the porcelain.

This may be distinguished from the film formed by antimony under similar circumstances by (1) its greater metallic lustre, and (2) by its dissolving on the addition of chlorinated soda (Labarraque's solution) ; (3) moisten the spot with nitric acid ; evaporate the acid ; a white stain is left, which is colored a red by $AgNO_3$ and yellow by H_2S. The flame should now be extinguished and the delivery tube made to dip into a solution of $AgNO_3$.

FIG. 31.

FIG. 32.

This will be blackened, and if overlaid with aqua ammoniæ, a yellow precipitate will appear at the junction of the two fluids.

ANTIMONY (*stibium*) occurs native, and usually as a sulphide. Prepared by roasting the sulphide, and heating with charcoal the oxide thus obtained.

Properties.—A bluish-white, crystalline solid, with a brilliant metallic lustre. Resembles metals and forms alloys. In chemical reactions it plays the role of positive and negative radical with equal facility.

Used in alloys, as type metal, Babbit's metal, Britannia, etc., to which it gives hardness and causes them to expand and fill the molds on solidifying. The metal is not used in medicine and pharmacy, most of the compounds being obtained from the sulphide.

HYDROGEN ANTIMONIDE.—SbH_3 (*Stibine*), corresponding to AsH_3. This gas is formed wherever hydrogen is generated (nascent) iu presence of a reducible antimony compound.

ANTIMONIOUS CHLORIDE.—$SbCl_3$. At ordinary temperatures a yellow semi-solid ; hence called *butter of antimony*. On addi-

tion of considerable water it decomposes, precipitating a white powder, the *oxychloride* (SbO.Cl),[105] formerly called *powder of algaroth.*

ANTIMONY OXIDES AND OXACIDS.—These are analogous to those of phosphorus and arsenic, but of little importance either in medicine or the arts.

ANTIMONIOUS OXIDE.—Sb_2O_3. Prepared by treating the oxychloride with sodium carbonate to remove the chlorine. A whitish, insoluble, volatilizable powder.

ANTIMONY AND POTASSIUM TARTRATE.—*Tartar Emetic.*—Made by boiling 3 parts of Sb_2O_3 and 4 parts of cream of tartar in water, filtering and evaporating.

$$2KHC_4H_4O_6 + Sb_2O_3 = 2K(SbO)C_4H_4O_6 + H_2O$$

Potassium Bitartrate   Tartar Emetic
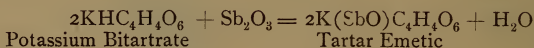
Colorless crystals of a sweetish, metallic taste; soluble in water and slightly so in alcohol. The only officinal salt of antimony, soluble without decomposition, and therefore more used in medicine than the others combined, *e. g.*, in the officinal *vinum antimonii, unguentum antimonii* and *syrupus scillæ compositus.*

ANTIMONIOUS SULPHIDE.—Sb_2S_3, the principal ore of antimony; occurs native in black, lustrous masses. It may be precipitated from any antimonial solution by H_2S as an orange powder, which is black when thoroughly dried.

Medical.—Antimony salts, especially the soluble tartar emetic, are local irritants externally, expectorants in doses of fractions of a grain, emetics in larger doses, and in excessive doses gastro-intestinal irritants; one and a half grains (0.1 Gm.) have killed, though recovery has occurred from vastly larger quantities, owing to the prompt emesis it produces.

Antidote.—Tannic acid forms with it an insoluble (and therefore harmless) compound, but its best antidote is ferric hydrate,

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[105] SbO and BiO, called respectively *antimonyl* and *bismuthyl*, are univalent radicals, because two valences of the trivalent element being satisfied by the bivalent O, only one free valent is left.

the same as for arsenic ; so one need not wait to determine if the poisoning be by arsenic or antimony.

Tests.—The presence of antimony may be detected by the plating and hydrogen tests just as arsenic, but differentiated [106] from that element by the sublimate from the plating being amorphous and the metallic mirror being insoluble in chlorinated soda solution ; also by H_2S giving an orange-red precipitate soluble in ammonium sulphide and in strong HCl, but unlike As_2S_3 insoluble in ammonia water.

BISMUTH occurs native and as a sulphide. Prepared by roasting the sulphide in air, and reducing the resulting oxide with charcoal.

Properties.—A brittle, white metal,[107] with a bronze tint ; volatilizes at a white heat. Forms compounds closely analogous to those of Sb, but is more positive, and plays the negative role with less facility.

Used in alloys ; *e. g.*, pewter and stereotyping metal ; the latter melts in boiling water.

Bismuth Nitrate—Bi_3NO_3.—Formed by treating bismuth with nitric acid.[108] Dissolves in a little water, but if much water be added it decomposes, with precipitation of—

Bismuth Subnitrate—$BiONO_3$ (Bismuth Oxynitrate) [109] — A white, tasteless powder, much used in medicine and as a cosmetic (pearl white).

Bismuth Subcarbonate—$(BiO)_2CO_3$.—Similar to the preceding in constitution, properties and uses.[110]

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[106] Repeat the *hydrogen sulphide* test (99), the *hydrogen* test, the *plating* test (103), and *demonstration* 104, using a solution of tartar emetic instead of arsenic, and note the peculiarities of antimony.

[107] *Metallic Bismuth.* Secure a lump of the metal and study its physical properties.

[108] *Bismuthous Nitrate.* Heat an excess of the metal with strong HNO_3 and preserve the solution (Bi_3NO_3) for the subsequent experimentation.

[109] *Bismuth Subnitrate.* Let fall a few drops of the solution into a beaker of water and note white precipitate of $BiONO_3$.

[110] *Bismuth Subcarbonate.* To a second portion add ammonium carbonate and note white precipitate of $(BiO)_2CO_3$.

Bismuth and Ammonium Citrate.—Obtained in pearly scales by dissolving the citrate in dilute ammonia-water, evaporating to a syrupy consistence and spreading on glass to dry. Being very soluble it is the preparation used in making the popular elixirs of bismuth.
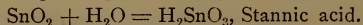
Physiological.—The bismuth salts are tonic, sedative, mildly astringent and antifermentative. Used to allay gastro-intestinal irritation. Occasionally the irritation is increased from presence of arsenic which unscrupulous manufacturers often fail to remove as the Pharmacopœia directs.

When preparations of bismuth are taken, the stools are blackened by the sulphide formed with the H_2S in the intestines. In severe cases of diarrhœa, with acid fermentation, this blackening does not occur, and its reappearance is a sign of improvement.

V. Carbon Group.

CARBON (*carbo*, a coal),	........C,	12
SILICON (*silex*, a flint),	.......Si,	28
TIN (*Stannum*),	..............Sn,	118
LEAD (*Plumbnm*),	............Pb,	207
PLATINUM	...................Pt,	195
IRIDIUM	....................Ir,	193
OSMIUM,	..................Os,	191
PALLADIUM,	..................Pd,	106
RUTHENIUM,	..................Ru,	101
RHODIUM,	..................Rh,	104

Each element is bivalent and quadrivalent. Their dioxides form with water dibasic acids :—

$$CO_2 + H_2O = H_2CO_3, \text{ Carbonic acid.}$$
$$SiO_2 + H_2O = H_2SiO_3, \text{ Silicic acid.}$$
$$SnO_2 + H_2O = H_2SnO_3, \text{ Stannic acid.}$$
$$PbO_2 + H_2O = H_2PbO_3, \text{ Plumbic acid.}$$

[111] *Bismuthous Sulphide.* Through a third portion pass H_2S and note black precipitate of Bi_2S_3.

[112] To another portion add a bit of zinc and note black deposit of metallic Bi.

CARBON *occurs free* in its three allotropic forms, diamond, graphite, and coal ; *combined* in carbonates and in all animal and vegetable substances. All its forms are probably traceable to organized life.

Diamond.—Geological history unknown ; transparent crystalline body of great brilliancy ; hardest substance known. Used as a gem and for cutting glass, etc.

Graphite (to write).—Owing to its resemblance to lead it has been called *black lead* or *plumbago ;* almost pure carbon. Used for pencils, crucibles, stove polish, etc., and as a lubricant.

COAL.—*Mineral coal* is a black substance, compact in texture,

FIG. 33.
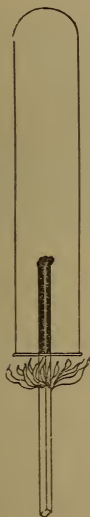
FIG. 34.
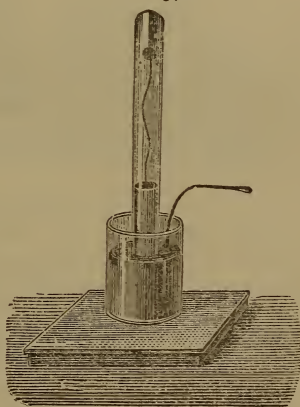
the remains of vegetable life of past ages. *Charcoal* is obtained by burning heaps of wood with a limited supply of air.[113] The

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[113] *Charcoal by incomplete combustion.* Push a lighted match-stick slowly up into the mouth of a small test-tube. (Fig. 33.) Note the incomplete combustion, and that the stick is converted into charcoal.

6

volatile constituents pass off, leaving the carbon as a light, porous substance, retaining the form and structure of the wood.[114] *Animal charcoal* is made by heating animal matters in closed iron retorts. Charcoal, especially animal, is a valuable absorbent of odorous gases[115] and coloring matters.[116]

Soot or lampblack is a very finely divided carbon, deposited by the heavy smoke from the incomplete combustion of tar, oils, or other substances rich in carbon.[117]

Properties.—Free carbon is solid at all temperatures, and insoluble in all menstrua. Ordinarily, free carbon is unaffected by chemical agents, but at high temperatures it surpasses most other elements in its avidity for O. Hence it is used to separate the metals from their oxides.[118]

CARBON MONOXIDE—CO.—*Occurs* whenever carbon is burned with an insufficient supply of air, as in anthracite stoves and furnaces, and in coal-gas, but never occurs in nature.

Prepared in the laboratory by heating oxalic acid,[119] or potas-

---

[114] Pack match-sticks side by side in the lower part of a small tube and heat as strongly as the glass will stand. Note the gases, vapors and tarry fumes evolved from the destructive distillation. When these have about ceased to come off, remove the tube from the flame and cork it up. When cool examine the charcoal residue.

[115] Fill a test-tube with ammonia gas over mercury (Fig. 34). Introduce a piece of charcoal recently heated. The gas is absorbed, as is shown by the rapid rise of the mercury.

[116] To a solution of indigo, cochineal, or potassium permanganate or beer in a flask, add some animal charcoal, shake up and filter. The filtrate is colorless, and in case beer is used it has also lost its bitter taste.

[117] *Lampblack.*—Hold a cold porcelain dish in a candle flame, the flame of a gas jet or of a Bunsen burner with the air-holes closed. Note the deposit of lampblack.

[118] Into a slight depression in a piece of charcoal lay some metallic oxide, *e. g.*, lead oxide; heat with a blow-pipe. The oxide is reduced by the heated charcoal around it, and globules of the metal appear which coalesce into a bright button.

[119] *From Oxalic Acid and H_2SO_4.*—Into a side-neck test-tube put 5 gm. of oxalic acid and H_2SO_4 enough to cover it. Connect a delivery tube and wash-bottle containing KHO, (or use flask as arranged in Fig. 35), and heat strongly
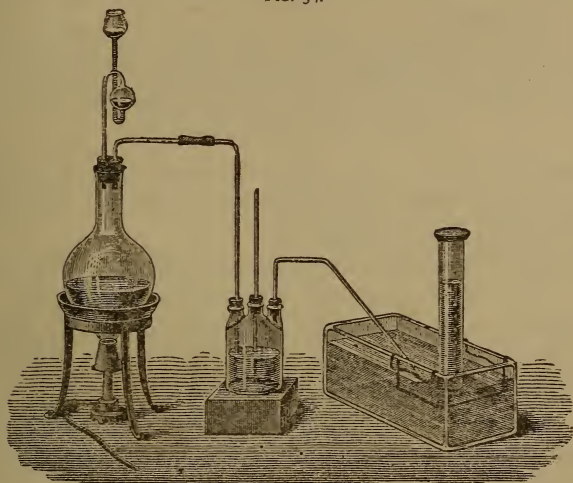
$$H_2C_2O_4 + H_2SO_4 = H_2SO_4 + CO_2 + H_2O + CO.$$

The CO_2 is absorbed by the KHO in the wash-bottle, and the CO is collected in tubes over water.

sium ferrocyanide, with sulphuric acid, or by heating a mixture of charcoal and cupric oxide.[120]

Properties.—Colorless, odorless, tasteless gas; burns with a pale blue flame; very poisonous, combining with the coloring

FIG. 35.

Making CO.

matter of the blood corpuscles, and destroying their oxygen-carrying power. Artificial respiration is of little use. Transfusion of blood is the most promising treatment. After death the blood remains scarlet. The sources of danger are open charcoal fires, defective draught in stoves and chimneys, and illuminating gas escaping into bed-rooms.

CARBON DIOXIDE—CO_2.

$$CO_2 + H_2O = H_2CO_3—\text{Carbonic acid.}$$

[120] Let two students working together prepare carbon monoxide by *incomplete combustion of carbon*. Mix equal parts of powdered charcoal and black oxide of copper, and put into a side-necked test-tube with delivery tube as in Fig. 8; heat as strongly as the glass will stand, and collect the CO in tubes over water. Note the properties of the gas, and search the residue for granules of metallic copper.

Occurs sparingly (.0003) in the atmosphere, as a result of animal respiration, vegetable decay, and combustion. Plants absorb it, appropriating the carbon and returning the oxygen to the air.

It often accumulates in cellars, beer-vats, wells, etc., where it is called choke-damp.[127]

Prepared by burning carbon; but most conveniently, in the laboratory, by decomposing a carbonate with an acid.[121]

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$
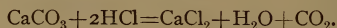
Physical Properties.—Transparent, colorless gas, of a pungent odor and sour taste. One and a half times as heavy as air.[122] Water dissolves its own volume.[123]

Chemical Properties.—Neither burns nor supports combustion.[124] In water it exists as carbonic acid—H_2CO_3. On attempting to concentrate this dilute solution the acid decomposes again into water and CO_2; hence wet litmus reddened by it becomes blue again on drying.

The carbonates of the potassium group are all soluble, and not decomposable by heat, all others are insoluble [125] and decomposable by heat.

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[121] Put about 30 Gm. (one ounce) of marble dust ($CaCO_3$) in a flask with delivery tube and pour in HCl through the funnel; collect the gas by downward displacement in a good-sized glass jar. Note its color and behavior to moistened blue litmus paper; taste and smell it by sucking it up through a glass tube.

[122] To show the weight of carbon dioxide: (1) Pour it from one vessel to another. (2) Blow soap bubbles and allow them to fall into a wide vessel containing this gas. As soon as they reach the surface of the gas they stop and float upon it. (3) Pour a large beakerful of the gas into a light pasteboard box that has been balanced on a pair of scales. The box will at once descend.

[123] That water will dissolve a greater quantity of carbon dioxide under pressure is shown by the rapid evolution of the gas whenever a bottle of soda or other carbonated water is opened and the pressure thereby removed.

[124] Set a candlestick, holding several lighted tapers at different heights, in a large jar. Carbon dioxide is introduced at the bottom, and extinguishes the tapers one by one as the vessel fills up to their levels.

[125] To each of four test-tubes add, respectively, solution of $CaCl_2$, $MgSO_4$,

Uses.—CO_2 is the principal food of plants.   Combustion [126] and the oxidation of decaying vegetation and the respiration of animals [127] add vast quantities to the air ; plants absorb this and the green coloring matter (chlorophyl) in their leaves decomposes it, the carbon going into the structure of the plant and the oxygen returning to the air.   Besides its employment in the manufacture of carbonates, CO_2 is extensively used in beverages, making them effervescent, sparkling and of an agreeable, pungent

FIG. 36.
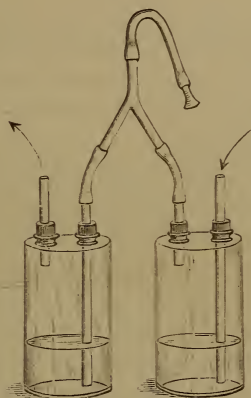
taste. "Soda water" is simple water charged with about 5 volumes of CO_2 and flavored with any desired fruit-syrup.   For this purpose, CO_2 is now sold liquefied in strong steel cylinders under a pressure of 40 atmospheres (600 lbs.).   The evaporation of this liquid is sometimes used in laboratory work for the production of intense cold (—110 C.).

$FeSO_4$, and $Pb(C_2H_3O_2)_2$.   Pass CO_2 into each and note the precipitation of the carbonates of these metals.   Add a few drops of acid to each and note that the precipitates dissolve with effervescence of CO_2.

[126] Set a short candle into a glass jar and put the cover on.   When the candle is extinguished remove it and add lime-water and shake thoroughly. Note the white precipitate of $CaCO_3$.

[127] That this gas accumulating in wells can be bailed out in buckets, may be illustrated by dipping it out of a glass jar and pouring it on to a small lighted candle.

Tests.—(1) The gas (15 per cent. and over) extinguishes a flame ; (2) precipitates lime-water ; (3) carbonates effervesce on adding a strong acid.

Physiological.—If the gas be undiluted, death is immediate from spasm of the glottis. If somewhat dilute (15 to 30 per cent.) there is loss of muscular power, anæsthesia, and death without a struggle. If quite dilute (5 to 10 per cent.) headache, giddiness, muscular weakness, and sometimes vomiting and convulsions occur.

The effects are more serious if the CO_2 comes from combustion or respiration, because of the removal of oxygen and the admixture of the deadly CO and animal exhalations.

Treatment.—Fresh air, artificial respiration, and stimulation. The preventive is ventilation.

VENTILATION.—More than 7 parts of CO_2 in 10,000 of air is oppressive. Taking this as the maximum impurity allowable, 3,000 cubic feet of fresh air per hour is needed by each person, and more in case of disease or when lamps are burning. To secure this in a room containing 1,000 cubic feet ($10 \times 10 \times 10$), the air must be changed three times an hour. This would give a draught not uncomfortable or injurious. If the draught be properly distributed, a breathing space of 500 cubic feet changing six times an hour would be unobjectionable. Ventilation may be secured in two ways, by diffusion and by draught.

Diffusion.—Gases mingle more rapidly, liquids more slowly, to make a mixture of uniform density.

When two gases of different densities are separated by a porous partition, they mingle, the lighter passing through more rapidly than the heavier, the rapidity being in inverse ratio to the square roots of their densities.[129]


[12b] Two Wolff bottles are half filled with lime-water and arranged as in Fig. 36. Placing the rubber tube in his mouth, the operator can inspire through one bottle and expire through the other. The small amount of carbon dioxide in the inspired and the larger amount in the expired air are shown by a white precipitate, slight tn the one and dense in the other bottle.

[129] Cement a porous earthenware battery cup at its open end to the top of a

This diffusion is more active in winter than in summer, because of the greater difference in density of the warm air within the house and the cold air without. Damp walls are unhealthy, mainly because being no longer porous they prevent this diffusion.

FIG. 37.

CYANOGEN—CN or Cy. Univalent because N^{III} can satisfy only three valences of C^{IV}. A compound negative radical resembling in its chemical behavior the elements of the chlorine group.

Prepared by strongly heating mercuric cyanide.[130]

$$Hg(CN)_2 = Hg + 2CN.$$
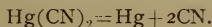
A colorless gas, smelling like peach kernels. Burns with a peach-blossom flame; unites with metals to form cyanides, the most important being—

HYDROCYANIC ACID—H(CN), or HCy—*Prussic Acid, Hydrogen Cyanide).—Occurs* in bitter almonds, cherry-laurel water, etc.

Properties.—Colorless liquid, having an odor like peach kernels. For medical purposes only a dilute (2 per cent.) solution is used, and the dose is from two to five drops.

funnel tube, the end of which dips into a bottle of colored water, as in Fig. 37. Bring down over the cup an inverted bell jar of hydrogen. The light H diffuses so much faster into the cup than the air diffuses out of it, that bubbles of gas escape rapidly through the water. Remove the bell jar and the conditions are reversed. The H now diffuses so rapidly out of the cup that the water is sucked up the tube.

[130] Heat Hg2CN in a side-necked test-tube with delivery-tube, and note the properties of the CN gas evolved. If mercuric cyanide cannot be obtained, a mixture of two parts of thoroughly dried potassium ferrocyanide and three parts mercuric chloride may be used. Remember Hg2CN is exceedingly poisonous.

[131] Experiments 122, 123, 124, 128 and 129 had better be performed by the instructor in the presence of the class.

Toxicology.—All the cyanides are very poisonous. One drop of the pure acid produces immediate death, and three grains of potassium cyanide kills in a few minutes. The respiratory centres are paralyzed, and the victim falls and dies in convulsions. Poisoning is liable to occur from handling the acid or the cyanides, which are largely used in the arts, or from eating vegetable products, *e. g.* peach and cherry seeds containing *amygdalin,* a substance easily decomposing into prussic acid and other products. Owing to the rapid action of the poison, antidotes are usually impracticable. Use artificial respiration and stimulate. If the patient survive an hour, the prognosis is good.

Tests.—(1) Its odor; (2) silver nitrate—white precipitate soluble in boiling HNO_3; (3) add ammonium hydrosulphide, evaporate to dryness, and then add ferric chloride—a blood-red color.

CYANATES.—Cyanic acid (HCyO) and ammonium cyanate (NH_4CyO) are the most interesting. The latter on being heated in aqueous solution forms urea.

SULPHOCYANATES are sulpho-salts corresponding to the cyanates (oxy-salts), and are good illustrations of the facility with which S forms series of compounds analogous to those of O. They, especially the potassium and sodium salts, are used as test reagents.

COMPOUND CYANIDES.—Cyanogen shows a great tendency to form complex radicals, especially with iron : as *ferrocyanogen* $[Fe^{II}(CN)_6{}^I]^{IV}$ or $(FeCy_6)^{IV}$, and *ferricyanogen* $[Fe^{III}(CN)_6{}^I]^{VI}$ or $(FeCy_6)^{VI}$. These two radicals contain ferrous and ferric iron respectively, and with hydrogen form acids (hydracids) known as *hydro-ferrocyanic acid,* H_4FeCy_6 (tetrabasic), and *hydro-ferricyanic acid* $H_3Fe(CN)_6$ or H_3FeCy_6 (hexabasic) ; the salts of these acids are termed ferrocyanides and ferricyanides.
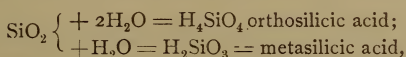
POTASSIUM FERROCYANIDE.—K_4FeCy_6—commonly called *yellow prussiate of potash,* and POTASSIUM FERRICYANIDE—K_3FeCy_6—*red prussiate of potash,* are important test reagents.

The carbon compounds will be further considered under the head of Organic Chemistry.

SILICON (also called *silicum*) resembles carbon, and occurs in three allotropic forms corresponding to coal, graphite and diamond; most abundant element after oxygen. It exists in only a few compounds, but they constitute the larger part of the earth's crust. Its principal compound is its oxide.

SILICON OXIDE.—SiO_2—SILICA occurring as sand, chalcedony, agate, onyx, quartz, etc., and as a constituent of granite and other abundant rocks. Colorless, except when tinted by the oxides of certain metals as in the amethyst and other gems; insoluble and unaffected by most reagents except HF and fused alkalies.

SILICIC ACID occurs in two varieties:

$$SiO_2 \begin{cases} + 2H_2O = H_4SiO_4 \text{ orthosilicic acid;} \\ + H_2O = H_2SiO_3 = \text{metasilicic acid,} \end{cases}$$

When sodium silicate is treated with hydrochloric acid $Na_4Si_4 + O\ 4HCl = 4NaCl + H_4SiO_4)$ and the $NaCl$ dialyzed out orthosilicic acid remains, colorless, tasteless, and only faintly acid to litmus. If this be evaporated and mildly heated it loses one molecule of H_2O and becomes metasilicic acid (H_2SiO_3) which by further heating gives off the second H_2O and is converted into silica (SiO_2).

Silicates of aluminum and magnesium are very abundant, as clay, soapstone, asbestos, etc. Glass is a mixture of several silicates, usually of sodium, calcium and sometimes lead. It is made by melting sand (SiO_2) with the carbonates or oxides of the metals. The addition of certain metallic oxides gives color; *e. g.*, cobalt gives a blue, manganese an amethyst, and copper a ruby. If the glass consist of only an alkaline silicate (*e. g.*, sodium silicate), it is *soluble* or *water-glass*, which is largely used in surgical dressings.

THE METALS.—*Occurrence.*—Some, as gold and copper, occur free, but most of them are found combined with non-metallic elements, especially sulphur and oxygen.

Preparation.—If combined with sulphur the ore is roasted until the sulphur is burned out, leaving the metal as an oxide, which is then heated with carbon to remove the oxygen, thus:

$$ZnS + O_3 = ZnO + SO_2; \text{ then, } ZnO + C = CO + Zn.$$
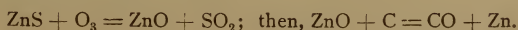
Physical Properties.—Very opaque, with a " metallic lustre " (in fine pow-
der, a dull black); bluish-gray, varying between the pure white of silver and
the dull blue of lead. Yellow gold and red copper are exceptions. In weight,
varying greatly, as between lithium, specific gravity 0.58, and platinum, specific
gravity 21.50. Most are solid, except mercury (liquid) and hydrogen (gas-
eous). All are absolutely insoluble in water as long as they are in the metallic
state.

Chemical Properties.—Electro-positive, possessing great affinity for the non-
metals and other electro-negative radicals. When two metals are fused to-
gether the product is an *alloy.* If one of the metals be mercury, it is called
an *amalgam.* Alloys are not chemical compounds, but mixtures, for the
metals do not unite in definite proportions, and the alloy is not a new sub-
stance, but one with properties intermediate between those of its constituent
metals.

Used mostly in the arts. Of the fifty-five metals only about twenty-six, or
rather compounds of these, enter the materia medica, and merit our notice.

TIN.—A bluish-white malleable metal, not corroded by air or
water ; hence used to form a protective coating for iron and cop-
per. *Tin-ware* is usually sheet-iron coated by being dipped into
molten tin. *Tin-foil* (thin laminæ of tin) is used in wrapping to
exclude air and moisture. Tin enters into the composition of a
great many alloys. Alloyed with lead it is easily dissolved, and
may cause lead poisoning, especially in those using cheap canned
goods and tobacco wrapped in tin-foil. Powdered tin is some-
times used as an anthelmintic.

Tin forms two classes of compounds : the *stannous,* in which
the atom is bivalent, and *stannic,* in which the atom is quadriva-
lent. These are of importance to the chemist, but of little inter-
est to the physician.

LEAD.—Its principal ore is its sulphide (PbS), called *galena.*
It is a soft, heavy blue metal,[132] very slowly acted upon by most
substances ; hence used to make water-pipes and vessels that are
exposed to corrosive liquids.

Water containing nitrates or nitrites (from organic matter)

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[132] Heat some litharge on charcoal with the reducing flame of the blow-
pipe, and note globules of metallic lead, and the physical properties of the
metal.

dissolves lead slightly; but if it contains carbonates or sulphates, the lead is protected by an insoluble coating of lead carbonate or sulphate.

Lead enters into the composition of many alloys: as pewter, solder, shot, type-metal, etc. The quadrivalent compounds of lead are of so little importance that the term *plumbic* generally is applied to the bivalent compounds.

LEAD OXIDE.—PbO—*Litharge.*—A yellow substance, found native; made artificially by heating lead in the air. It is by treating this with the appropriate acid that most of the lead salts are prepared. When rubbed with oil it decomposes the glycerylic ethers and combines with the fatty acids to form lead soaps, one of which, the oleate, is *lead plaster, emplastrum plumbi*, U. S. P.

LEAD DIOXIDE, or *puce lead*, is a dark-brown powder,[133] forming one of the constituents of *red lead* (Pb_3O_4 or $2PbO.PbO_2$).[134]

Prepared by treating *red lead* with nitric acid to dissolve out the PbO.

LEAD NITRATE—$Pb(NO_3)_2$.

Made: $PbO + 2HNO_3 = Pb(NO_3)_2 + H_2O$.

Ledoyen's disinfectant fluid was a solution of $Pb(NO_3)_2$ (one drachm to the ounce), but is no longer officinal. It corrects fetid odors by precipitating H_2S and NH_4HS.

LEAD ACETATE—$Pb(C_2H_3O_2)_2$, or $PbAc_2$—*Sugar of lead*.[135]

Made: $PbO + 2HAc = PbAc_2 + H_2O$.

Used in medicine more than any other lead salt. Its solution will dissolve considerable quantities of PbO, forming the *solution*

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[133] Onto 1 Gm. of red lead in a test-tube pour 5 Cc. of dilute HNO_3 and note that the acid attacks and dissolves only the PbO, leaving the PbO_2 as a dark brown powder.

[134] Mix a little dry PbO_2 with pulverized sugar and note that when the pestle rubs hard against the side of the mortar, the sugar is oxidized by the PbO_2 and takes fire.

[135] Heat 2 Gm. of litharge with 5 Cc. of acetic acid and filter. Allow a few drops of the filtrate to evaporate on a watch crystal and note the colorless prismatic crystals of "sugar of lead."

of the subacetate of lead, the *liquor plumbi subacetatis*, U. S. P., *Goulard's extract*. This is a basic acetate and is sometimes called vinegar of lead. It is astringent, and, like all the lead salts, sedative. Much used as a topical application in erysipelas, acute eczema, and other skin affections ; and diluted (*lead water*), it is used in conjunctivitis and other mucous inflammations.

The following insoluble salts may be made by precipitation from solutions of the preceding soluble ones : [136]

LEAD CHLORIDE—$PbCl_2$.—*Made:* Soluble lead salt added to a soluble chloride ; *e. g.*, $PbAc_2 + 2HCl = PbCl_2 + 2HAc$. Slightly soluble in warm water, but in cold it is always precipitated from solutions of moderate strength ; hence classed with HgCl and AgCl as one of the three insoluble chlorides.

LEAD SULPHATE—$PbSO_4$.—Forms as a white precipitate whenever a solution of a lead salt is added to a sulphate solution, thus :

$$PbAc_2 + ZnSO_4 = PbSO_4 + ZnAc_2.$$
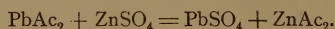
LEAD CARBBNATE—$PbCO_3$—*White Lead*.

Made: $PbAc_2 + Na_2CO_3 = PbCO_3 + 2NaAc$.

Commercially, it is made by some modification of the old Dutch method, which consists in covering sheets or bars of lead with the refuse of the wine-press and barn manure. The acetic fumes from the grape husks attack the lead, forming lead acetate, which is decomposed by the carbonic acid ($CO_2 + H_2O$) from the manure. The acetic acid thus liberated combines with another portion of

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[136] Now test this filtrate for lead, by adding to successive portions the following solutions, each containing a negative radical capable of forming an insoluble compound with Pb :

Sulphuric Acid. ($PbAc_2 + H_2SO_4 = 2HAc + PbSO_4$) white precipitate.

Hydrosulphuric Acid. ($PbAc_2 + H_2S = 2HAc + PbS$) black precipitate.

Sodium Carbonate. ($PbAc_2 + Na_2CO_3 = 2HAc + PbCO_3$) white precipitate.

Potassium Iodide. ($PbAc_2 + 2KI = 2HAc_2 + PbI_2$) yellow precipitate.

*Potassium Chromate.* ($PbAc_2 + K_2CrO_4 = 2HAc_2 + PbCrO_4$) yellow precipitate.

lead, which is again precipitated by the carbonic acid, and thus the process continues until all the lead is consumed.

Used for painting, but blackens when air contains H_2S.

LEAD SULPHIDE—PbS—is formed as a black precipitate whenever a lead solution is treated with a soluble sulphide, as H_2S or NH_4HS.

LEAD IODIDE—PbI_2.—A bright yellow precipitate on adding a soluble iodide to a lead solution; as,

$$PbAc_2 + 2KI = 2KAc + PbI_2$$
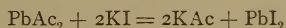
LEAD CHROMATE—$PbCrO_4$.

Made: $PbAc_2 + K_2CrO_4 = PbCrO_4 + 2KAc$.

Under the name of *chrome yellow* it is used in painting. Of late it has been used to color food products.

Tests for lead consist mainly in forming precipitates of the foregoing insoluble compounds.

Physiological.— All the lead compounds are poisonous. *Acute* poisoning sometimes occurs from the ingestion of a single large dose of a soluble lead salt. The symptoms are those of gastric irritation. *Treatment:* Give $MgSO_4$ to form the insoluble $PbSO_4$.

The *chronic* form of lead intoxication, *painter's colic*, is true poisoning, and is produced by the continued absorption of minute quantities of lead by the skin of those handling it, and by the lungs and stomachs of those living in painted apartments, or using food and drink from leaden vessels or soft and contaminated water conveyed through lead pipes. There is impairment of digestion, constipation, blue line along the edge of the gums, colic and paralysis, especially of the extensor muscles. Lead once absorbed is eliminated very slowly, having combined with the albuminoids, a combination which is rendered soluble by the administration of iodide of potassium.

The *treatment* for chronic lead-poisoning is to give $MgSO_4$, for the double purpose of overcoming the constipation and precipitating any lead remaining unabsorbed in the alimentary canal; also KI to promote the elimination of that which is combined with the albuminoids. Alum is a favorite treatment, seeming to

perform all accomplished by both the $MgSO_4$ and KI. The paralyzed muscles must be treated with electricity, so that when the lead is eliminated and the nerve influence returns, it may not find them degenerated past redemption.

Potassium Group.

(HYDROGEN ....H................... 1)
LITHIUM ....Li 7
AMMONIUM ....(NH_4) 18
SODIUM (Natrium).............Na 23
POTASSIUM (Kalium)...........K 39.1
RUBIDIUM ....Rb 85
CÆSIUM.......................Cs 133

Group Characteristics.—Univalent ; very electro-positive (except H), so that when combined, unless it be with a strongly electro-negative (acidulous) radical, they form very alkaline compounds. The positive affinities, as in the other groups, increase with the atomic weights. All their compounds are soluble.

LITHIUM.—Sparingly but widely distributed in nature, especially in the waters of certain springs. Lightest of the solid elements. Its salts closely resemble those of sodium.

Physiological.—Lithium urate being by far the most soluble compound of uric acid, salts of lithium, especially the very soluble citrate and the less soluble carbonate,[147] are given to gouty persons to promote the elimination of uric acid, which accumulates in that disease. But much of the lithium seems to go to neutralizing the acid sodium phosphate instead of combining with the uric acid.
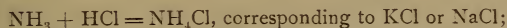
Test. It colors the flame a beautiful carmine red ;[138] its phosphate is insoluble in presence of ammonium hydrate.[139]

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[147] LITHIUM. *Tests.* Note the taste, reaction and slight solubility (1 in 80) of Li_2CO_3; dissolve a little in HCl, avoiding excess of acid, and test the solution.

[138] *Flame.* Dip end of platinum wire in solution and place in edge of the Bunsen flame and note the carmine-red.

[139] *Phosphate.* Into a test-tube pour some Na_2HPO_4 solution and half as much NH_4HO and then a few drops of the Li solution, and warm slightly. Note white precipitate of Li_2HPO_4.

AMMONIUM.—When ammonia gas (NH_3) combines with an acid, it appropriates the basic hydrogen of the acid and forms a salt in which NH_4 is the positive radical; *e. g.:*

$NH_3 + HCl = NH_4Cl$, corresponding to KCl or $NaCl$;
$NH_3 + HHO = NH_4HO$, corresponding to KHO or $NaHO$;
$NH_3 + HNO_3 = NH_4NO_3$, corresponding to KNO_3 or $NaNO_3$;
$2NH_3 + H_2SO_4 = (NH_4)_2SO_4$, corresponding to K_2SO_4 or Na_2SO_4.
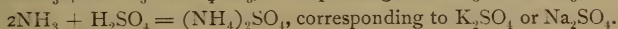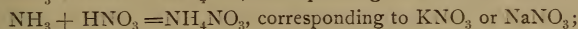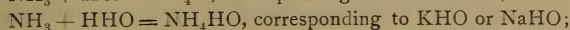
This radical (NH_4) plays the *rôle* of a metal, like K and Na, and is called *Ammonium.* Does not exist uncombined, although Weyl claims to isolate it as a dark-blue liquid metal.[140] We can obtain it as amalgam by the reaction between sodium amalgam and ammonium chloride.[141]

AMMONIUM HYDRATE—NH_4HO—*Caustic Ammonia*—is formed in solution whenever ammonia gas (NH_3) dissolves in water, thus: $NH_3 + H_2O = NH_4HO$. It has been already stated that the aqueous solution of a fixed substance is called a *liquor;* of a volatile substance, an *aqua.* In like manner alcoholic solutions of fixed substances are called *tinctures,* and of volatile, *spirits.* There are four U. S. P. solutions of ammonia :

Aqua ammoniæ............................ ....*10 per cent.*
Aqua ammoniæ fortior........................*28* "
Spiritus ammoniæ...........................*10* "
Spiritus ammoniæ aromaticus. " "

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[140] NOTE.—*The supposed free ammonium.* Sodio-ammonium is prepared by heating sodium in a sealed tube with ammonia gas. This is in turn heated with ammonium chloride in a sealed tube. A dark-blue liquid, with metallic lustre, is obtained, but soon decomposes into ammonia gas and hydrogen.

[141] To some mercury in a test-tube add sodium, small bits at a time. On this sodium amalgam pour a strong solution of ammonium chloride. Sodium chloride and ammonium amalgam are formed.

$$(Na + Hg) + NH_4Cl = NaCl + (NH_4 + Hg).$$

The ammonium amalgam swells up and soon decomposes--$(NH_4 + Hg) = NH_3 + H + Hg$--the gaseous NH_3 and hydrogen escape, and only the mercury remains.

In each of these solutions NH_4HO exists, but has never been isolated, because, whenever we attempt to evaporate the water or alcohol, the NH_4HO decomposes into $NH_3 + H_2O$.[142] Ammonium hydrate is very alkaline.

AMMONIUM HYDROSULPHIDE—NH_4HS—*occurs* in decomposing nitrogenous, sulphurized organic bodies. *Made* by saturating a solution of NH_4HO with H_2S. A yellowish solution; used as a test reagent.

AMMONIUM CARBONATE—$(NH_4)_2CO_3$.—*Ammonii Carbonas*, U. S. P.[143]—*Sal volatile*—is prepared by heating a mixture of NH_4Cl and chalk ($CaCO_3$) up to the temperature at which $(NH_4)_2CO_3$ would be volatilized, when the following reaction will occur.[144]

$$2NH_4Cl + CaCO_3 = CaCl_2 + (NH_4)_2CO_3$$
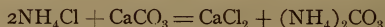
(See *Volatility*, page 33.) Very prone to absorb CO_2 from the atmosphere and become bicarbonate unless NH_4HO be added.

OTHER SALTS may be made by adding the appropriate acid to the carbonate or hydrate of ammonium. If we use the carbonate we can tell when acid enough has been added by the cessation of effervescence. If the hydrate is used there is no effervescence, and our only guide is the point at which the solution becomes neutral in reaction. This is determined by the use of test papers. These are made of white, unsized paper, steeped in a blue vegetable pigment called *litmus*, which is *reddened* by *acids* and *restored* to its *blue* by *alkalies*.

Physiological.—The hydrate and carbonate are alkaline irritants,

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[142] *Ammonium Tests.* NH_4HO. Pour aqua ammoniæ into a test-tube and note (*a*) the odor and alkalinity of the escaping NH_3, (*b*) white fumes of NH_4Cl when a glass rod moistened with HCl is brought near the mouth of the tube, and (*c*) that after boiling, the water has become almost tasteless and neutral.

[143] The officinal dry salt consists really of ammonium bicarbonate and carbamate, but the latter on dissolving in water becomes normal ammonium carbonate.

[144] *Carbonate.* Heat a mixture of chalk ($CaCO_3$) and sal ammoniac (NH_4Cl) and hold an inverted beaker over the mouth of the test-tube. Note the sublimate in the beaker and its odor, taste, solubility and reaction.

like the corresponding K and Na compounds, though in less degree. They moreover give off NH_3, which, though irritating to the respiratory tract, is a valuable stimulant in fainting fits, etc. Two drachms of aqua ammoniæ have killed. The treatment, as *for all alkalies*, is to give a dilute acid or some oil.

Tests.—(1) An ammonium salt warmed with liq. potassæ gives off NH_3, recognized [145] (*a*) by its odor, (*b*) its forming a white cloud of NH_4Cl when a glass rod dipped in the HCl is held over the vessel, and (*c*) its changing moist red litmus to blue. (2) Heat the dry ammonium salt and it volatilizes.[146] (3) Platinic chloride[147] gives a creamy yellow precipitate, and (4) Nessler's[148] reagent, a brown coloration.

SODIUM.— *Occurs* very abundantly in sodium chloride, or common salt, and from it almost all the other sodium compounds are now obtained, instead of from the ashes of sea-weeds as formerly. Sodium resembles potassium very closely, except that sodium is a little less positive and its compounds manifest the alkaline tendency a little less strongly. As a rule the sodium salts tend to effloresce and the potassium salts to deliquesce on exposure to the air. But the compounds of the two metals are so alike in their preparation, properties and uses that the physician's or chemist's choice between them is usually determined by such considerations as economy, convenience, solubility, etc. Hence of the sodium compounds we will notice only a few as being of particular importance.

SODIUM CHLORIDE.—NaCl, or common salt, is very abundantly

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[145] *NH₃ from Salts.* To an ammonium salt in a test-tube add KHO solution and warm. Note the NH_3 evolved and recognize it as above suggested.

[146] *Sublimation.* Heat some impure NH_4Cl in a large test-tube and note that it sublimes and collects in pure white masses in the upper part of the tube.

[147] *Platinic Chloride.* To a few drops of ammonium salt on a microscope slide or watch-glass add one drop of HCl and a drop of $PtCl_4$ (an expensive reagent), and note the yellow precipitate of $PtCl_4 2NH_4Cl$.

[148] *Nessler's.* To an extremely dilute solution of an ammonium salt add a few drops of Nessler's reagent and note the brown coloration and the great delicacy of the test.

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and widely distributed, occurring in most animal and vegetable tissues, and in all natural waters, especially sea water. Where arms of the sea and salt lakes have evaporated through ages, deposits of rock salt are found, often of vast extent, as at Stassfurt in Germany and Petite Anse in Louisiana. When pure it is not hygroscopic, though common salt is usually slightly deliquescent on account of the presence of magnesium salts.

Sodium Dioxide.—Na_2O_2—"peroxide of sodium" is a yellowish, very caustic solid and has recently assumed commercial importance as an oxidizing, bleaching and disinfecting agent, for with water it yields about 20 per cent. of oxygen ($Na_2O_2 + H_2O = 2NaHO + O$) and with dilute acids produces hydrogen dioxide ($Na_2O_2 + 2HCl = 2NaCl + H_2O_2$).

Sodium Bicarbonate—$NaHCO_3$—*baking soda*. Effervescing mixtures such as Seidlitz powders and baking powders generally consist of sodium bicarbonate and potassium bitartrate mixed dry. In some cheaper varieties of baking powders alum and acid calcium phosphate are used instead of the cream of tartar. On the addition of water the following reaction occurs with evolution of CO_2:

$$NaHCO_3 + KHC_4H_4O_6 = NaKC_4H_4O_6 + H_2O + CO_2.$$
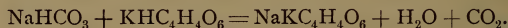
Sodium Sulphate—$Na_2SO_4.10H_2O$ or *Glauber's Salt* and

Sodium Phosphate—Na_2HPO_4—are useful saline purgatives; and

Sodium Sulphite—Na_2SO_3—is used in preventing fermentation and as a reducing agent in photography.

Tests.—No good precipitant; for all the compounds of sodium are soluble. However, the strong yellow color it gives a flame is a very delicate test; in fact, often annoyingly delicate, for it shows traces of sodium in almost everything.

POTASSIUM *occurs* only in compounds. *Prepared* by heating one of its oxygen compounds with charcoal in an iron retort ($K_2CO_3 + 2C = 3CO + K_2$). The metallic K distills over and is condensed in a flat receiver.

Physical Properties.—Soft as wax; lighter than water; silvery lustre when freshly cut, but quickly tarnishes.

Chemical Properties.—Intensely electro-positive ; hence it possesses great affinity for the non-metals ;[149] takes O from H_2O,[150] even as ice,[151] setting fire to the escaping H, and giving the flame the violet color characteristic of K (Fig. 38).

FIG. 37.   FIG. 38.

POTASSIUM CARBONATE.—K_2CO_3.—Obtained as an impure solution ("lye") by lixiviating the ashes of plants, especially forest trees. This, evaporated to dryness, forms "concentrated lye" or "potash." This in turn when purified forms "pearl-ash," which

FIG. 39.
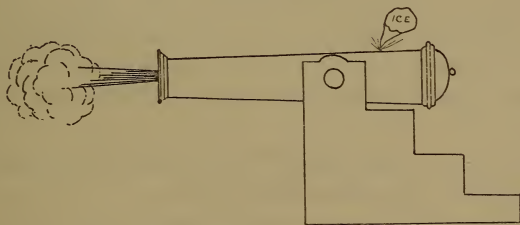
is further purified for medicinal use. Sometimes made by burning cream of tartar and lixiviating the residue ; hence called *salts of tartar*. A white semi-crystalline or granular powder. CO_3

POTASSIUM. *Metal.* Let the instructor ([149]) inflame a bit of metallic K by lowering into a jar of chlorine, Fig. 37, or ([150]) make an explosion by warming it with iodine or dropping it into bromine, taking care to cover the experiment with a bell jar. [151] Load a strong toy cannon with gun-powder, lay a small bit of K in the fuse and touch off with a piece of ice. Fig. 39.

being a weakly acidulous (negative) radical, K_2CO_3 is very alkaline, even caustic.[152]

ACID SALTS.—Salts are formed by a metallic radical displacing the basic H of an acid. If all the H is displaced, the result is a *normal salt*, as, $H_2SO_4 + K_2 = K_2SO_4 + H_2$. But if part of the basic H of the acid remains, it is called an *acid salt*, as $H_2SO_4 + K = KHSO_4 + H$. Sometimes acid salts are called "bi" salts, because the proportion of the acidulous radical to the basylous is twice as great as in the normal; *e. g.*, $KHSO_4$ is called potassium bisulphate, because the proportion of the acidulous radical SO_4 to the basylous radical K is twice as great as in the normal sulphate, K_2SO_4.

POTASSIUM BICARBONATE—$KHCO_3$.—Although an acid salt in constitution, it is alkaline in reaction, on account of the weakness of its acidulous radical. Made by passing CO_2 into a solution of K_2CO_3. The reaction is as follows :—

$$K_2CO_3 + H_2O + CO_2 = 2KHCO_3.$$

POTASSIUM BITARTRATE—$KH(C_4H_4O_6)$ or KHT—*Cream of Tartar.*—Prepared similarly to the above, by adding tartaric acid to a solution of the normal tartrate, thus : $K_2\overline{T} + H_2 = 2KH\overline{T}$. It exists naturally in grape juice, and, being insoluble in an alcoholic menstruum, is precipitated on the sides of the wine casks whenever vinous fermentation sets in. This is its commercial source.

OTHER SALTS.—Most salts of K are made by treating the carbonate with the appropriate acid, *e. g.* :—

The chloride—$K_2CO_3 + 2HCl = 2KCl + H_2O + CO_2$.
The sulphate—$K_2CO_3 + H_2SO_4 = K_2SO_4 + H_2O + CO_2$, etc.
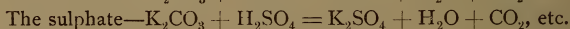
The decomposition is attended with an effervescence of CO_2. It is the formation of this volatile compound that determines the reaction. (See *Volatility*, page 33.)

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[152] Let the student drop a bit of K into a beaker one-fourth full of water, Fig. 38, and cover quickly. Note (*a*) that the liberated hydrogen ignites instantly and burns with a violet flame, exploding at the close; (*b*) that the water has a soapy taste and feel; (*c*) that it is alkaline, and (*d*) HCl neutralizes it without effervescence, showing absence of carbonate.

But the following salts are not made in that way :—

POTASSIUM HYDRATE—KHO—*Caustic Potash*—may be made experimentally by the reaction of metallic K on water, thus :—

$$H_2O + K = KHO + H.$$
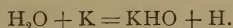
But made in the shops by boiling K_2CO_3 with slacked lime, thus :—[153]

$$K_2CO_3 + Ca2HO = CaCO_3 + 2KHO.$$
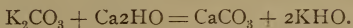
The insoluble $CaCO_3$ (chalk) sinks to the bottom, and the KHO dissolves in the supernatant liquid, which when clear is poured off (decanted). This watery solution, if of proper strength (5 per cent.), forms "*Liquor potassæ*, U. S. P." If this solution is evaporated to a syrupy consistence and poured into moulds, it forms the stick caustic potash. KHO is very alkaline, and a powerful caustic.[154]

Exposed to the air it absorbs CO_2 and forms the carbonate :—

$$2KHO + CO_2 = K_2CO_3 + H_2O.$$

POTASSIUM IODIDE—KI :—

$$6KHO + 6I = 5KI + KIO_3 + 3H_2O.$$

The color disappears because the I goes to form colorless salts. The iodate[158] being a disagreeable and otherwise undesirable contamination, the mixture should be strongly heated to decompose the iodate ($KIO_3 = KI + O_3$) leaving only KI. The addition of charcoal facilitates the removal of the oxygen.

POTASSIUM BROMIDE—KBr—may be made like the foregoing.

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[153] KHO.—Boil 100 Gm. of K_2CO_3 in water in an iron dish and add lime until a sample of clear liquid does not effervesce with an acid. Allow the $CaCO_3$ to subside and then decant the clear solution of KHO.

[154] *Causticity.* Add portions of this KHO solution to three test-tubes.[155] To one add some animal matter as wool and boil, noting that the wool is soon dissolved; [156] to another add some vegetable fibre as cotton or paper, and note that the fibre swells up and after considerable boiling dissolves; [157] in the third boil some fat and note that the fat is soon emulsified and dissolved forming soap, and that it lathers on shaking and that when HCl is added the fat-acids separate and float on in an oily-looking layer.

[158] *Iodate.* To detect the presence of KIO_3 in a commercial specimen of

POTASSIUM NITRATE—KNO_3—*niter, saltpeter,* occurs in nature but so sparingly that until the introduction of the cheaper Chili saltpeter ($NaNO_3$) it was produced in large quantities artificially on the so-called saltpeter plantations by mixing wood ashes and manure in heaps and allowing them to lie for several years and slowly decay. In the presence of air, moisture and certain nitrifying organisms the nitrogen of the manure is oxidized and combines with the potassium in the ashes forming KNO_3, which is separated by lixiviation or "leaching." It is often noticed as a white efflorescence on compost-heaps. It is used in medicine and pharmacy ; and very much in the arts, especially in the manufacture of gunpowder and fireworks, on account of the ease with which it gives up its oxygen to combustible substances.[161]

SODIO-POTASSIUM TARTRATE—$Na K\overline{T}$—*Rochelle Salt.*—A neutral salt made by boiling acid potassium tartrate with sodium bicarbonate.

$$KH\overline{T} + NaHCO_3 = NaK\overline{T} + H_2O + CO_2.$$

This is the reaction that occurs in bread-making with cream of tartar baking powders.

POTASSIUM HYPOCHLORITE—$KClO$.—Made by passing chlorine into a cold solution of KHO. Yields free chlorine. The ordinary bleaching solutions (Labarraque's Solution or Javelle water) are impure solutions of the hypochlorite of sodium or of potassium.

Tests for Potassium.—(1) If the suspected solution is concen-

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KI : boil a grain of starch in water in a test-tube; add a crystal of the suspected KI and then a few drops of tartaric acid. If KIO_3 be present iodine is liberated and strikes a blue with the starch.

[159] *Other Hydrates.* Add a few drops of the KHO to test-tubes containing respectively, $CaCl_2$, $FeSO_4$, and $CuSO_4$. Note the appearance of the precipitated hydrate of each metal and that they all dissolve when acidulated with HNO_3 or other strong acid.

[160] *Carbonates.* Refill each test-tube and repeat the preceding experiment except using K_2CO_3 instead of KHO solution. Note appearance and behavior of the respective carbonates.

[161] *Nitrate.* Carefully neutralize 5 gm . of K_2CO_3 solution with HNO_3, stopping when effervescence ceases; dip a strip of paper in it and ignite it when dry. Note that it burns like tinder.

trated, add H_2T and get a precipitate of $KH\overline{\overline{T}}$.[162] (2) Platinic chloride ($PtCl_4$) gives a yellowish precipitate.[163] But the $PtCl_4$ is very costly, and all the potassium compounds so soluble that the above tests are but little used. The most convenient is the (3) flame test; dip[164] the end of a clean platinum wire in the suspected solution, and hold in the colorless Bunsen or alcohol flame and notice the violet color.

CÆSIUM AND RUBIDIUM. — Rare metals, occurring in small quantities with potassium. Discovered in 1860 by means of the spectroscope, and named from the colors of their lines in the spectrum; *cæsius*, sky blue, and *rubidus*, dark red. Of no medical interest as yet.

ACIDIMETRY AND ALKALIMETRY.

VOLUMETRIC ANALYSIS depends on the fact that all substances combine in certain definite and fixed proportions—elements in the proportions of their atomic weights and compounds in the proportions of their molecular weights.

$$\underbrace{\overset{\text{HCl}}{1 + 35.5}}_{36.5} + \underbrace{\overset{\text{KHO}}{39.1 + 1 + 16}}_{56.1} = \underbrace{\overset{\text{KCl}}{39.1 + 35.5}}_{74.6} + \underbrace{\overset{\text{HO}}{1 + 16}}_{18}$$

So that by measuring the quantity of one substance entering into a complete reaction we can readily estimate the others. For

---

[162] *Bitartrate Test.* To a solution of a K salt add a strong solution of tartaric acid, first adding a little alcohol to make the more delicate. Note the precipitate of sodium potassium tartrate.

[163] *Platinic Chloride Test.* To a few drops of a potassium solution on a glass slide or watch glass add a drop of alcohol and then a drop of $PtCl_4$, and note creamy precipitate of $PtCl_4 2KCl$.

[164] *Flame Test.* Dip tip of a platinum wire into a potassium solution and hold it in the Bunsen flame, and note the delicate violet color, best observed through a piece of blue glass to intercept any yellow from accidental admixture of sodium salt.

[165] *Analytical.* To determine whether a salt be a compound of K, Na, NH_4, or Li, heat samples of each; the one that volatilizes is the salt of NH_4, Confirm this by boiling with KHO and getting the odor of ammonia. To the other three salts apply the flame tests, getting the violet for K, yellow for Na, and carmine for Li.

convenience these measuring (volumetric) solutions are each made by dissolving in a liter (1000 Cc. or grams) a number of grams equal to the molecular weight of the substance as com-

FIG. 40.

FIG. 42.
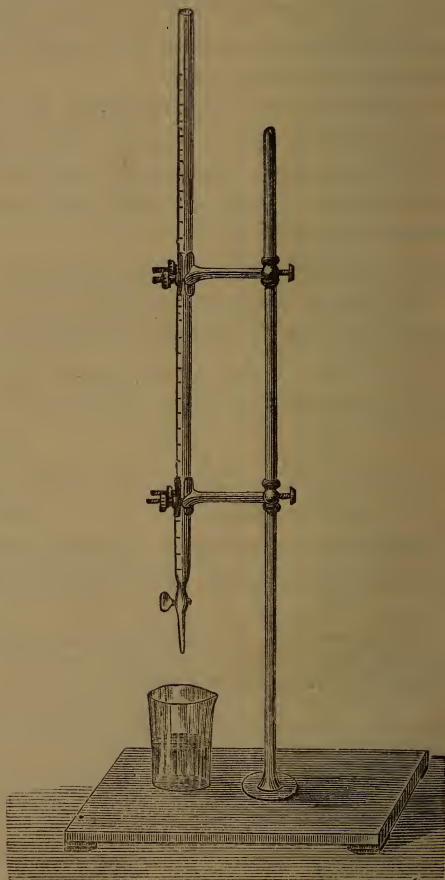
FIG. 41.

pared to one atomic weight of hydrogen, counting in of course the water of crystallization, if any, entering into the molecule. So a certain volume of one solution is exactly the chemical

equivalent of the same volume of another solution. Such solutions are called *normal* volumetric solutions. Whenever a more dilute solution is desired, it is made one-tenth or one-hundredth of the normal strength and called a *decinormal* or *centinormal* solution. The necessary apparatus consists only of a graduated pipette Fig. 40, a liter-flask Fig. 41, and a burette Fig. 42. A burette is a long narrow tube with some sort of a stop-cock at its lower end and with accurate graduations by which the amount of liquid drawn off can be accurately read.

To estimate the quantity of an alkali or of an acid in a specimen, a certain volume of it is measured out and a few drops added of an "indicator," usually a dye-stuff that will change color at the point of neutralization and mark the end of the reaction. Then after first noting the height in the burette of the test solution, this is added cautiously, especially towards the end, with constant stirring until the color changes (the end of the reaction). The amount of the test solution used from the burette is read off, and from this the quantity of the opposite substance in the specimen is easily calculated.[166]

Calcium Group.

CALCIUM, ...Ca.................... 40
STRONTIUM, ...Sr.................... 87.5
BARIUM, ...Ba....................137

Bivalent; their oxides and hydrates are very *alkaline,* but of an *earthy* character. Their positiveness or basicity is in the order of the atomic weights. Their carbonates are decomposable by heat and insoluble in water, unless it contains H_2CO_3 in solution. Their sulphates decrease in solubility from the slightly soluble calcium sulphate to the extremely insoluble barium salt.

---

[166] Exercise. Measure into a beaker 5 Cc. of KHO solution and add a drop or two of phenolphthalein, and note that it instantly turns pink. Now add the acid test solution very slowly and with constant stirring until the pink suddenly disappears. Then multiply the number of cubic centimeters of the test solution used by the factor for KHO (equivalent in 1000 being .0561). In a similar way "titrate" solutions of HCl, etc., for practice.

CALCIUM.—Never free, but its compounds are very abundant, as limestone,[167] gypsum, etc. Calcium salts are necessary to animal life, the teeth and bones consisting mainly of calcium phosphate.

CALCIUM CHLORIDE—$CaCl_2$.

Made : [168] $CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$.

A white salt ; very avid of water and deliquescent ; used to dry gases.

CALCIUM CARBONATE—$CaCO_3$.—Abundant as limestone, marble, corals, chalk, and shells of the crustacea, mollusks, etc. Chalk consists of microscopic shells. *Precipitated chalk* is made [169] by adding a soluble carbonate to a soluble calcium salt, as :—

$$Na_2CO_3 + CaCl_2 = 2NaCl + CaCO_3.$$
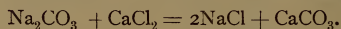
The precipitate ($CaCO_3$) may be separated from the NaCl in solution, by—

(*a*) *Filtration.*—Pouring the mixture into a cone of filter paper placed in a funnel, when the water with the dissolved salt will pass through, leaving the insoluble portion (the precipitate) on the filter. (*b*) *Decantation.*—Allowing the precipitate to settle to the bottom, and pouring off the clear fluid.   In either case the precipitate may be freed from any remaining NaCl by adding pure water and repeating the process. $CaCO_3$ is slightly soluble in the presence of free H_2CO_3.

CALCIUM OXIDE—CaO—*Lime, quicklime; calx*, U. S. P.—A white solid ; made by heating limestone [171] in furnaces called kilns.

CALCIUM.

[167] *Flame.* Dip a little lump of marble into HCl and hold it in the Bunsen flame—a red flash.

[168] To an excess of chalk in a test-tube add dilute HCl.   Note effervescence of CO_2, and when it ceases filter or decant.

[169] To the clear solution add some carbonate (as of K, Na or NH_4) and note white " precipitated chalk."

[170] In a side-neck test-tube with delivery tube generate CO_2 from HCl and lump of marble.   Conduct the gas into lime-water.   Note that $CaCO_3$ is at first precipitated and afterwards redissolved by the CO_2.

[171] Heat a little lump of marble white-hot.   Note that it loses its crystalline appearance, and becomes CaO.

$$CaCO_3 == CaO + CO_2.$$
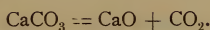
When water is added to CaO there is a violent chemical union, great heat is evolved, and a hydrate is formed [172] thus :—

$$CaO + H_2O = Ca(HO)_2.$$
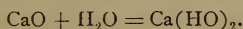
CALCIUM HYDRATE—Ca2HO—*Slacked lime.*—A white odorless powder; very slightly soluble in water, less than one grain to the ounce, but enough so to give "lime-water" (*liquor calcis*, U. S. P.) a decidedly alkaline taste and reaction. The presence of sugar greatly increases its solubility (*liq. calcis saccharatus*, Br.).

CHLORINATED LIME—*Chloride of lime, bleaching powder, calx chlorata*, U. S. P.—is a mixture of chloride of calcium ($CaCl_2$) and calcium hypochlorite ($CaClO_2$. It is made by passing chlorine gas over slacked lime until it ceases to be absorbed. It is white, moistens on exposure to the air, absorbing CO_2 and giving off Cl. It is employed as a source from which to get a gradual supply of chlorine for disinfecting and bleaching purposes.

CALCIUM SULPHATE—$CaSO_4$ [173]—*occurs* native as gypsum, which, when heated, loses its water of crystallization [174] and forms a white amorphous powder called *plaster-of-Paris.* If this plaster be mixed with water enough to form a creamy liquid, it will re-crystalize or "set" into a hard compact mass.[175] Much used in surgery to make casts to hold broken limbs in position. Very slightly soluble in water.[176]

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[172] Let the CaO cool, and then drop it into a test-tube and add a few drops of water. Note that it combines with the water, swells up and the tube feels hot.

[173] To an inch (about 5 Cc.) of $CaCl_2$ solution add a few drops of $MgSO_4$ and note white precipitate of $CaSO.2H_2O$.

[174] Heat carefully in a test-tube a lump of natural gypsum ($CaSO_4.2H_2O$) or fragment of an old plaster cast. Note that the water of crystallization escapes and condenses on the sides of tube and the gypsum loses its crystalline character.

[175] Mix some plaster of Paris into a paste with water and pour into a pill box; press into the surface a greased coin or key. After it "sets" remove the coin or key and the pill box, and note the cast and the impressions.

[176] To water that has been standing on $CaSO_4$ in a test-tube add $BaCl_2$ and note white precipitate of $BaSO_4$, showing the extent to which $CaSO_4$ dissolves in water.

CALCIUM PHOSPHATE—$Ca_3(PO_4)_2$.[178] It is the most abundant mineral ingredient of the body ; is in every tissue and fluid, especially the teeth and bones, to which it gives hardness and rigidity. A white tasteless powder, soluble in dilute acids. Dissolved by lactic acid, it is given as *syrupus calcii lactophosphatis*, U. S. P., in scrofula, rickets, and other diseases of defective nutrition.

CALCIUM OXALATE—CaC_2O_4, or CaOx—*occurs* in the juices of some plants and in the urine. Obtained as a fine white crystalline powder when a soluble oxalate is added to a calcium solution.[177] Insoluble in water or acetic acid, but soluble in the mineral acids.

CALCIUM CARBIDE—CaC_2.—This new compound,[179] important commercially as a cheap source of the valuable illuminant acetylene and interesting chemically as bridging over the chasm between inorganic and organic substances, and enabling us to make an organic compound directly from the elements, was discovered almost accidentally a few years ago. A young man was operating an electric furnace in a small aluminum works on the little river Spray, in North Carolina, and happened one day to throw in some lime and coal. Instantly they fused into a dark lustrous mass, which he soon threw into the mill-pond. The vigorous bubbling of gas which ensued completed the discovery of a new and cheap method of manufacturing acetylene, $(CaC_2 + 2H_2O = Ca(2HO)_2 + C_2H_2)$. Acetylene is exceedingly rich in carbon, and burns with a smoky flame, but with a proper admixture of air gives a light of intense whiteness and power.

HARD WATERS are such as contain mineral matters, especially calcium (lime) compounds. Often water, in passing through the soil, becomes highly charged with carbonic acid, and dissolves

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[177] Repeat preceding, adding oxalic acid ($H_2C_2O_4$), and note white precipitate of CaC_2O_4, insoluble in alkalies and weak acids but soluble in strong HCl.

[178] To a calcium solution add Na_2HPO_4 and note white precipitate of $Ca_3(PO_4)_2$, soluble even in weak and dilute acids.

[179] *Acetylene.* Into a beaker of water drop a small lump of CaC_2 and note a copious, white precipitate of $Ca(2HO)_2$ and a rapid bubbling of C_2H_2, which is easily recognized by its pungent odor and bright smoky flame when ignited.

considerable amounts of $CaCO_3$, and is hard. This is called *temporary hardness*, because on exposure or boiling, the carbonic acid is driven off, the $CaCO_3$ is precipitated, and the water becomes *soft*. The solubility of $CaSO_4$ does not depend on the presence of carbonic acid, and so boiling will not precipitate it. So water impregnated with $CaSO_4$ is said to be *permanently hard*. Drinking-water should contain a small quantity of lime ; but very hard water impairs digestion. Hard water is unfit for washing, because the soluble alkali soap reacts with the lime salt to form an insoluble lime-soap.[180]

STRONTIUM.—This is a yellowish lustrous metal, occurring never free but always in compounds resembling and analogous to those of calcium, but far less abundant. Through the studies of Laborde, See, Solomon and others, strontium has recently come to be recognized as the best base for iodine, bromine, salicylic acid, etc., as it is non-toxic, sedative to the stomach and is said to have a peculiar nutritive influence. Since strontium colors the flame red [182] its salts, especially the nitrate, are used in pyrotechny to make "red fire."

BARIUM.—Of little interest to the medical student, except

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[180] Half fill two test-tubes, one with distilled and the other with hard water; add to each a few drops of soap solution and shake thoroughly. Note that the distilled water quickly "lathers" and that the liquid is felt to strike the glass softly; and that the hard water strikes hard and does not lather, but forms a precipitate or curd (calcium soap).

[181] *Estimation of Hardness.* To 100 Cc. of the water in a clear vial add gradually from a burette the "standard soap solution," shaking after each addition and stopping when a permanent lather appears. Each Cc. of soap solution used represents one degree of hardness, *i. e.*, 1 part of $CaCO_3$ in 100,-000 parts of the water. A water with not over five degrees of hardness is classed as a soft water.

[182] STRONTIUM. *Flame.* Dip platinum wire into solution of $Sr(NO_3)_2$ and note the red color it gives the Bunsen flame.

[183] To solution of $CaSO_4$ in a test-tube add a strontium solution and note that $SrSO_4$ is precipitated, being more insoluble than $CaSO_4$.

[184] BARIUM. *Carbonate.* Add Na_2CO_3 to $BaCl_2$ solution and note the white precipitate of $BaCO_3$.

[185] Heat white-hot a lump of native $BaCO_3$ (witherite); add the resulting BaO to water and note that it "slakes" with evolution of heat and dissolves forming a solution of $Ba(HO)_2$.

that its compounds are poisonous. Barium sulphate is very insoluble;[186] hence (1) the antidote of barium is some soluble sulphate, and (2) barium solutions (nitrate and chloride) are delicate tests for sulphates, and *vice versâ*. (See *Insolubility*) Barium gives the flame a green color;[188] hence used (nitrate) in pyrotechny to make the green or Bengal light.

Magnesium Group.

MAGNESIUM, ...Mg................. 24
ZINC,.................   ....Zn 65.3
CADMIUM, ...Cd 112

Group Characteristics.—Bivalent ; bluish white-lustrous metals ; quite permanent in air, but when highly heated they volatilize and ignite, burning with a bluish-white light very rich in chemical rays. Magnesium is sometimes classed in the calcium group, but it is more closely allied to zinc.

MAGNESIUM.—Never free ; abundant in magnesian limestone ($CaCO_3.MgCO_3$). Asbestos, meerschaum, and soapstone are native silicates. Most natural waters contain its salts. Silvery-white metal ; burns with a brilliant white light, rich in chemical rays, and used in photographing caves and other dark places.[189]

MAGNESIUM SULPHATE—$MgSO_4$—*occurs* in the waters of various springs, as those at Epsom ; hence often called *Epsom salts*. Made artificially from the native carbonate, thus :—

$$MgCO_3 + H_2SO_4 = MgSO_4 + (H_2O + CO_2).$$
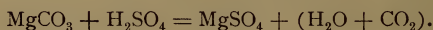
White, crystalline, soluble salt, of a nauseous bitter taste. It is

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[186] *Sulphate.* To a barium solution add a soluble sulphate and note white precipitate of $BaSO_4$. Let the precipitate settle, then pour off supernatant liquid and add HNO_3 and boil : it does not dissolve.

[187] To a barium solution add K_2CrO_4 : note yellow precipitate, insoluble in water but soluble in nitric and hydrochloric acid.

[188] *Flame.* Dip platinum into a solution of $BaCl_2$ and note that it colors the flame green.

[189] MAGNESIUM. *Metal.* Seize a piece of magnesium ribbon with the forceps; note its properties and then hold it in the Bunsen flame and note that it burns with a blinding bluish-white flame into a white powder of magnesia (MgO).

a popular purgative. The nauseous taste and griping may be obviated by adding sulphate of iron, as in Crab Orchard salts, or aromatics, or acids, by free dilution.

MAGNESIUM CITRATE is the most pleasant of the saline purgatives. Usually given as the *liquor magnesii citratis*, which is prepared by adding a solution of citric acid to $MgCO_3$, and bottling immediately to retain the CO_2.

MAGNESIUM CARBONATE—$MgCO_3$—*occurs* native. For medicinal purposes it is prepared by precipitation, thus :[190]

$$MgSO_4 + Na_2CO_3 = Na_2SO_4 + MgCO_3.$$

Similar to chalk in its physical and in its chemical properties.

MAGNESIUM OXIDE—MgO—*Magnesia*. Made like CaO, by heating the carbonate,[191] but is more mildly alkaline than CaO.

$$MgCO_3 = MgO + CO_2.$$
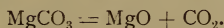
Insoluble and tasteless (earthy), but its alkalinity is shown by its turning moist red litmus paper blue when the solid MgO is dropped upon it.[192]

MAGNESIUM HYDRATE—$Mg(HO)_2$.—Formed by precipitating a magnesium solution with potassium or sodium hydrate. Insoluble in water, but, like other salts of magnesium, soluble in the presence of ammonium compounds with which they form double salts. Suspended in water, it is called *milk of magnesia*.[193]

MAGNESIUM PHOSPHATES.—These resemble the calcium phosphates and are associated with them in the body, though in small quantity. The *ammonio-magnesium phosphate* ($MgNH_4PO_4$) is

[190] To a solution of $MgSO_4$ add a few drops of Na_2CO_3. Note the white precipitate of $MgCO_3$, which dissolves on addition of NH_4Cl.

[191] Heat white-hot a lump of dry $MgCO_3$: let it cool and note that it is MgO ("calcined magnesia"), is alkaline to litmus and on the addition of acid dissolves without effervescence.

[192] With a clear glass rod rub a bit of this white powder on a bit of moistened red litmus paper and note that it gets blue, alkaline.

[193] Pour 5 Cc. of $MgSO_4$ solution in each of two test-tubes: to one add KHO and to the other NH_4HO. Note that NH_4HO precipitates only half as much $Mg(HO)_2$, the rest being held in solution by the ammonium salt. Add to the smaller precipitate strong NH_4Cl solution and it dissolves.

precipitated whenever a soluble phosphate in neutral or alkaline solution finds itself in the presence of an ammonium salt, as occurs in the alkaline fermentation of urine.[194]

Physiological. Magnesium oxide and hydrate being alkaline and tasteless, are popular antidotes for acids. These and the carbonate are given to correct acid conditions of the digestive tract, and combining with the acids they form soluble salts that are laxative.

ZINC.—When heated in air, zinc burns with an intense bluish-white light, forming clouds of oxide.[195] It tarnishes quickly in air or water, but becomes coated with a film of oxide that protects it from further corrosion. Iron coated with zinc ("galvanized iron") will withstand exposure to the weather an indefinite time. Alloyed with copper, zinc forms brass. Pure H_2SO_4 is unaffected by pure zinc or zinc coated with mercury (amalgamated), unless it forms a galvanic circuit.[196] Commercial zinc is rapidly attacked by most acids.

ZINC SULPHATE—$ZnSO_4$—*White Vitriol*—is made thus :—

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$
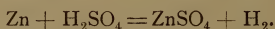
White, soluble salt, resembling $MgSO_4$ in appearance; astringent and emetic.

ZINC CHLORIDE — $ZnCl_2$—*Made :*[197] $Zn + 2HCl = ZnCl_2 + H_2.$ A white deliquescent salt, strongly astringent; severe caustic. Used as an injection or a bath to preserve anatomical subjects.

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[194] *Ammonio-Magnesium Phosphate.* To a $MgSO_4$ solution add NH_4Cl to prevent the precipitation of $Mg(HO)_2$ and then NH_4HO and finally Na_2HPO_4. Note the precipitation of ammonio-magnesium phosphate, the so-called " triple phosphate " in fern-like crystals.

[195] ZINC. *Metal.* After noting the color, lustre, weight, hardness, etc., of zinc, hold it in the Bunsen flame with forceps and see it volatilize and burn.

[196] *Sulphate.* Put bits of zinc in a test-tube and add dilute H_2SO_4. Note the heat produced and the vigorous evolution of hydrogen, which test by ignition, etc. Pour in a little mercury and agitate: the action ceases as soon as the zinc is amalgamated. Drop in a bit of copper and it begins again.

[197] *Chloride.* To bits of zinc in a test-tube add HCl and note the reaction, evolution of hydrogen. When action ceases, evaporate a few drops of the solution on a watch-crystal and note crystals of $ZnCl_2$.

Each of the following mixtures forms a hard, white mass, used for filling teeth :—

(*a*) A strong solution of zinc chloride with zinc oxide.

(*b*) A strong solution of magnesium chloride with magnesium oxide.

(*c*) Zinc oxide with phosphoric acid (zinc oxyphosphate).

ZINC CARBONATE—$ZnCO_3$—is a white, insoluble powder made by precipitation :—

$$ZnSO_4 + Na_2CO_3 = Na_2SO_4 + ZnCO_3.$$

Used in medicine as a dusting powder for excoriated surfaces, and in ointment.

ZINC OXIDE—ZnO—is prepared either by burning metallic zinc or heating the carbonate, $ZnCO_3 = ZnO + CO_2$.[198]

It is a yellowish-white powder, used *externally* in ointment ; *internally* as a tonic and astringent, especially in the night-sweats of phthisis and diarrhœa of children.

Zinc carbonate and oxide (pearl white) are often used as white pigment having the advantage of lead carbonate in not being blackened by sulphur compounds and in not being poisonous.

ZINC SULPHIDE—ZnS—is precipitated [199] whenever a solution of a zinc salt is added to the solution of a soluble sulphide, unless the solution is acid in reaction. It is the only white sulphide, therefore a test for zinc.

Poisoning.—All the salts of zinc that are soluble in the digestive fluids act as irritant poisons. Sodium chloride and organic acids dissolve metallic zinc ; therefore food kept in galvanized iron vessels is more or less poisonous, especially since commercial zinc usually contains traces of arsenic. For this reason articles in-

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[198] *Oxide.* Heat white-hot a lump of $ZnCO_3$ and note the resulting ZnO, and that it dissolves with acid without effervescence.

[199] *Precipitates.* Test successive portions of a solution of a zinc salt : (*a*) add Na_2CO_3 = white $ZnCO_3$; (*b*) add KHO = white $Zn(2HO)_2$, redissolved in excess of KHO but not reprecipitated by boiling or by NH_4Cl; (*c*) add NH_4HS = white ZnS soluble in excess and in acids except acetic; (*d*) add K_4FeCy_6 = white Zn_4FeCy_6, insoluble in HCl.

8

tended for toxicological analysis should never be kept in jars with zinc caps.

CADMIUM.—This is a comparatively rare metal; it is found in certain zinc ores; a bluish-white metal softer than zinc;[200] enters into several important alloys. Its salts resemble those of zinc in uses and properties except that some are employed in photography, and that its sulphide [201] is a bright yellow, insoluble in HCl and most acid solutions.[202]

Aluminum Group.

Group Characteristics.—Trivalent. Boron is so weakly positive that it is a non-metal. The others are rare metals, except aluminum, the most abundant of metals. So many of their compounds, especially the oxides, hydrates and silicates, are of a neutral, insoluble, infusible, inert and *earthy* character that the group is often called "the metals of the earths."

BORON occurs in the boric acid of the steam-jets in certain

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[200] CADMIUM. *Metal.* After noting the physical properties of a bit of cadmium, heat it under the blow-pipe and note that it burns, but with the formation of a *brown* oxide.

[201] To a solution of $CdSO_4$ add NH_4HS and note yellow precipitate of CdS.

[202] *Sulphide.* Add HCl to the cadmium in a test-tube and pass H_2S and note yellow precipitate of CdS.

volcanic regions and in deposits of borax, especially in California and Nevada. Boron has two allotropic forms, amorphous and crystalline, corresponding to the coal and diamond forms of carbon. Boron colors the flame green.[203]

BORIC ACID $(B_2O_3 + 3H_2O = 2H_3BO_3 =$ (ortho) Boric acid) was formerly called boracic acid from its relation to borax, the sodium salt from which the element itself was named ; pearly scales,[204] soluble in water and alcohol, feebly acid, slightly bitterish, almost tasteless, and unirritating. Boric acid alone, or combined with glycerine (boroglyceride) is a very efficient and non-poisonous antiseptic.

BORAX is official as sodium borate $(Na_2B_4O_7.10H_2O)$ and often called sodium biborate, though it is properly a tetraborate. A soluble, mildly alkaline salt of some antiseptic power, and so is used as a wash for infectious and parasitic inflammations. When fused it combines with various oxides, and is therefore used to clean off metallic surfaces in soldering, brazing and welding.

ALUMINUM is never found free, but in the abundance and distribution of its compounds (clay and many common rocks) it ranks next to oxygen and silicon—third among the elements and first among the metals. It is a very light (sp. gr. 2.6) bluish-white malleable metal, practically unaffected by air, water and many acids, though HCl and the alkalies attack it energetically.[206] It is also acted upon by certain vegetable acids, especially in the presence of common salt. Its ores, though abundant, unfortunately do not yield the metal on being simply heated with carbon,[212]

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[203] To a crystal of borax add a few drops of H_2SO_4 and about 5 Cc. of alcohol; ignite and note the green color the H_3BO_3 gives the flame.

[204] BORON. *Boric Acid.* Heat 5 Cc. of water and about 1 Gm. of borax in a test-tube; to this saturated hot solution add HCl and note the separation of white crystals of H_3BO_3.

[205] Melt 1 Gm. of H_3BO_3 in an iron spoon (doll tin-spoons can be bought for a few cents a thousand) and it loses its $3H_2O$ and becomes a sticky, glassy mass of B_2O_3.

[206] ALUMINUM. *Metal.* Note the physical properties of a bit of aluminum; that it does not dissolve in H_2SO_4, HNO_3 or NH_4HO, but that in HCl or KHO it dissolves readily with the evolution of hydrogen.

but recently devised electric methods are now, especially at Niagara and at Neuhausen on the Rhine, increasing and cheapening the output. The metal is especially valuable in its alloys, giving to other metals increased strength, incorrodibility and facility of casting.

ALUMINUM OXIDE, Al_2O_3, occurs native as *corundum*, which when pulverized is *emery;* its finely crystallized forms, the *sapphire* and *ruby*, are now also made artificially.

ALUMINUM HYDRATE, $Al(HO)_3$, soluble in acids or excess of of alkalies, falls as a gelatinous precipitate whenever an aluminum solution is treated with an alkaline hydrate or carbonate.[207] It has such affinity for organic matters that it is sometimes used to purify water, and is largely employed as a " mordant " to fix organic colors in dyeing.[211]

ALUMINUM CHLORIDE—Al_2Cl_6—*Prepared* industrially in the manufacture of aluminum. A soluble, astringent salt. It absorbs and combines with H_2S, PH_3, and NH_3. An impure solution is sold as a disinfectant under the name *chloralum.*

ALUMINUM SULPHATE—Al_23SO_4. Made by treating white clay with H_2SO_4. It has properties similar to the foregoing.

ALUM—*Alumen.*—An alum is a double sulphate of a trivalent and univalent radical,[212] crystallizing in regular octohedra with 12 molecules of water of crystallization. Its constitution may be expressed thus :—

$$R_2^{III}3SO_4.R_2^{I}SO_4, \text{ or } 2R^{III}R\ (2SO_4).$$

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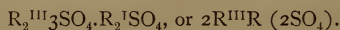
[207] *Hydrate.* To an aluminum solution (sulphate or chloride) add KHO and note gelatinous precipitate of aluminum hydrate, redissolving in excess of KHO. Note too that the same precipitate is formed ([208]) by NH_4HO; ([209]) by Na_2CO_3 with evolution of CO_2; and ([210]) by NH_4HS with evolution of H_2S.

[211] *Mordant.* Color an aluminum solution with cochineal and add NH_4HO; note that the precipitated hydrate takes the coloring matter and settles in red masses ("lakes") leaving the solution clear.

[212] *Alum.* Mix a solution of $Al_2(SO_4)_3$ with one of K_2SO_4 and evaporate until it crystallizes. Lay some of these alum crystals on a piece of charcoal and heat mildly with the blowpipe; note that they melt and lose their water of crystallization and become an amorphous mass of " burnt alum." Next heat as intensely as possible and note that the carbon of the charcoal does not reduce the aluminum compound to the metallic state.

The trivalent radical (R^{III}) may be Al, Fe, Cr, or Mn. The univalent radical (^{I}) may be K, Na, NH_4, etc. So by different combinations of these radicals a variety of alums may be formed. The old *potash alum* ($Al_2(3SO_4)_3.K_2SO_4$) is giving place in the arts to the cheaper *ammonium alum* ($Al_2(3SO_4)_3.(NH_4)_2SO_4$). The *ammonio-ferric alum* ($Fe_2(3SO_4)_3.(NH_4)_2SO_4$) is also much used in medicine. Burnt alum, *alumen exsiccatum*, is a white amorphous powder obtained by heating alum until its water of crystallization is driven off. Alum, like other salts in which the acidulous radical predominates, is astringent ; burnt alum, on account of its avidity for water, is a mild escharotic.

ALUMINUM SILICATES, very abundant in granite, feldspar, etc., and in the clays resulting from the disintegration of these rocks. Clay remaining where formed, is generally quite pure and white (kaolin or china-clay), but if deposited by water it is usually reddish or brown from admixtures of metallic oxides, especially iron.

Kaolin is used in medicine, from its inertness, as a dusting powder and as a vehicle for the application of certain corrosive chemicals. Pottery, earthenware and porcelain are made of clay mixed with some fusible silicate which, on heating, melts and binds the particles of clay together more or less firmly.

CERIUM is a rare metal. One of its salts, the oxalate, $Ce_2(C_2O_4)_3$, is used as a sedative to irritable stomachs, especially in the vomiting of pregnancy. When pure it is a very efficient remedy ; but the commercial article is liable to contain salts of lanthanum, neo- and praseodymium, and other allied metals.

The other members of this group are of little medical interest. The oxides of some of them—the "rare earths"—especially of cerium, together with zirconium and thorium, are used to make the mantle of the Welsbach burner, which heated in the air-gas (Bunsen) flame gives a strong white light.

X. The Iron Group.

These are hard metals and all more or less magnetic.

By a variation in valence they form two classes of compounds : One in which the atom is *bivalent*, as in ferrous chloride ($FeCl_2$) ; the other in which the atom is *trivalent*, as in ferric chloride $FeCl_3$. With excess of oxygen they form acidulous radicals, which form the chromates, manganates, and ferrates, with the stronger bases.

CHROMIUM.—So named because all its compounds are colored. The metal is of but little use. Its compounds are of great importance to the chemist and of considerable utility in the arts, but few are used in medicine.

CHROMIC OXIDE, Cr_2O_3, chromium sesquioxide, is a bright green powder used in paint as chrome-green.[213]

CHROMIUM TRIOXIDE—CrO_3—is made by treating a strong solution of potassium bichromate with sulphuric acid, thus :—

$$K_2Cr_2O_7 + H_2SO_4 = K_2SO_4 + H_2CrO_4 + CrO_3.$$

The CrO_3 separates in crimson prisms.[214] It is a powerful oxidant and a caustic. Sometimes improperly called chromic acid.

CHROMATES.—The principal ones are potassium chromate, K_2CrO_4, a valuable test reagent, and lead chromate, $PbCrO_4$, a yellow pigment.

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[213] CHROMIUM. *Sesquioxide.* Rub up together about 5 Gm. of $K_2Cr_2O_7$ and 1 Gm. starch; ignite this in an iron spoon; remove the K_2CO_3 by washing and then note the green mass of Cr_2O_3.

[214] *Trioxide.* Mix together equal parts of strong H_2SO_4 and saturated solution of $K_2Cr_2O_7$. Note as it cools the separation of crimson prisms of CrO_3.

BICHROMATES are not regular acid- or bi- salts, but compounds of a chromate and chromium trioxide. The most important of these is potassium bichromate, $K_2Cr_2O_7$, or $K_2CrO_4.CrO_3$. It forms large, red, soluble crystals. It is added to the sulphuric acid in batteries to oxidize [215] the nascent hydrogen.

Chromates may be recognized by their color and by the yellow precipitate on the addition of lead acetate.[222]

MANGANESE resembles iron in its properties. Used to alloy iron in the preparation of certain kinds of steel. Its most abundant ore is the

MANGANESE DIOXIDE—MnO_2—*Black Oxide of Manganese*—an insoluble steel-gray powder that readily gives us its extra atom of O. Used in large quantities in the preparation of chlorine and oxygen gas.[224]

MANGANOUS SULPHATE—$MnSO_4$.

$$MnO_2 + H_2SO_4 = MnSO_4 + H_2O + O.$$

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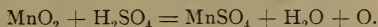
[215] *Oxidation.* Rinse a beaker with strong alcohol and drop in a crystal of CrO_3 and note that the thin film of alcohol ignites; ([216]) moisten a pledget of cotton with absolute alcohol and lay a crystal of CrO_3 on it, and it ignites; ([217]) boil some match-sticks with battery fluid ($K_2Cr_2O_7$ 10 per cent., water 80 per cent., and H_2SO_4 10 per cent.), and note that they are consumed with evolution of CO_2.

[218] *Chromic Salts* (green). To some $K_2Cr_2O_7$ solution in a test-tube add HCl and alcohol and boil. Note the odor of aldehyde from oxidation of the alcohol and the green color of $CrCl_3$. ([219]) To some $K_2Cr_2O_7$ solution add H_2SO_4 and alcohol, and boil; note the green color of $Cr_2(SO_4)_3$; put a few drops on a watch-glass and when it dries, note the crystals of chrome alum ($Cr_2 3SO_4 K_2SO_4$) or $KCr(SO_4)_2$.

[220] *Chromates.* To a solution of $K_2Cr_2O_7$ add KHO; note that K_2CrO_4 is formed and the solution becomes yellow. To successive portions of this K_2CrO_4 add ([221]) $BaCl_2$, and note yellow precipitate of $BaCrO_4$; ([222]) $Pb(C_2H_3O_2)_2$, and note yellow precipitate of $PbCrO_4$, and ([223]) $AgNO_3$ and note deep red of Ag_2CrO_4.

[224] MANGANESE. *Chloride.* Warm some MnO_2 and HCl in a beaker, under a hood or in the open air to avoid inhaling the Cl evolved, and filter. As the filtrate is sure to contain iron, add Na_2CO_3 gradually with constant stirring as long as reddish brown $Fe(HO)_3$ is thrown down and until the flesh-colored $MnCO_3$ begins to precipitate, then filter and label $MnCl_2$. To successive portions of the $MnCl_2$ solution ([225]) add NH_4HS and note a pale pink precipitate of MnS, the only flesh-colored sulphide known, and hence characteristic; ([226]) add NH_4HO and note flesh-colored precipitate of $Mn(HO)_2$ soluble in excess of NH_4HO.

A soluble, rose-colored salt, employed in medicine and also in dyeing.

MANGANOUS SULPHIDE—MnS—is precipitated whenever a solution of a salt of manganese is treated with NH_4HS. It is the only flesh-colored sulphide; hence its formation is a *test* of manganese.[225]

MANGANATES.—If a mixture of KHO, $KClO_3$, and MnO_2 is heated together, there results a green mass of *potassium manganate*, K_2MnO_4. If this is dissolved in distilled water, it forms a green solution, which, on boiling, or even standing awhile, is changed to a purple, owing to the formation of *potassium permanganate*, $K_2Mn_2O_8$.[227]

The permanganate [229] gives up its oxygen so readily to organic matter, at the same time losing its purple color, that it is used as a test for organic impurity in water and as a disinfectant.

Physiological.—Associated with iron (1 to 20), manganese is a normal constituent of the blood corpuscles; hence its preparations, like those of iron, are blood tonics. Valuable in amenorrhœa.

IRON *occurs* abundantly in oxide, carbonate, and sulphide; occasionally free, as in meteorites.

Preparation.—The oxides and occasionally the carbonates are the ones used for the preparation of iron. The oxide is heated in a blast furnace with coal and fluxes (limestone and silicates). The carbon of the coke removes the oxygen from the iron, which melts and sinks beneath the melted fluxes. The fused metal is

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[227] *Borax-bead.* Melt in the flame a lump of borax on the looped end of a platinum wire until it loses its water of crystallization and fuses into a clear glass bead; touch this to the manganese solution and again fuse it. Note that the bead is colored violet or amethystine.

[228] *Manganates.* Into a porcelain crucible put equal parts of MnO_2, KHO and $KClO_3$ and heat strongly. When quite cool add water and dissolve out the K_2MnO_4, which is a beautiful green. Pour some of this into a beaker of water and note that it changes to violet, $K_2Mn_2O_8$ with a precipitate of manganic hydrate.

[229] *Oxidation.* To some powdered $K_2Mn_2O_8$ in a dish add a few drops of H_2SO_4 and note the odor of ozone. ([230]) Add a few drops of strong alcohol and it ignites.

then drawn off into sand or iron molds. This is pig, or *cast iron*, containing 4 to 5 per cent. of carbon. *Wrought iron* contains little or no carbon [231] and *steel* an intermediate quantity.

Properties.—A bluish-gray metal, sp. gr. 7.5 ; rusts (oxidizes) when exposed to moist air or water containing air.

REDUCED IRON.—*Ferrum Redactum, iron by hydrogen*, Que-

FIG. 42.
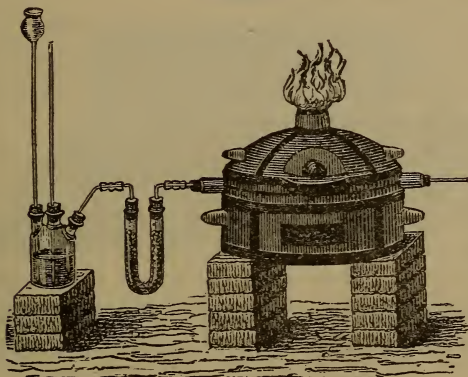
Making Reduced Iron.

venne's iron.—It is prepared by heating ferric oxide nearly to redness in a tube through which hydrogen is passed : [232]

$$Fe_2O_3 + H_6 = Fe_2 + 3H_2O.$$

It is a very fine, dark gray powder, which, if good and fresh, will ignite [233] on contact with a lighted taper and burn with a red glow ; prescribed in pill form.

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[231] IRON. *Metal.* Pour 10 Cc. of dilute H_2SO_4 into each of two test-tubes. Into one drop a small fragment of cast iron; into the other some wrought iron, as tacks; set aside, and when all is dissolved note that the cast iron leaves a residue of graphite carbon and the wrought iron leaves no residue.

[232] *Reduced Iron.* In the apparatus shown in Fig. 42 (rather tedious and troublesome for a class exercise) hydrogen is generated from sulphuric acid and zinc in the Wolff bottle, and dried by passing through the U-shaped tube containing calcium chloride. It then passes through the porcelain tube containing ferric oxide (subcarbonate, U. S. P.) which is heated to redness in the furnace. After the reduction is completed, the iron should not be exposed to the air until cool, or it will ignite spontaneously.

Let the student ([233]) (Faraday's experiment) pour a mixture of reduced

CHLORIDES.

FERROUS CHLORIDE—FeCl₂.—Made by adding iron to hydrochloric acid until effervescence ceases, thus :—

$$Fe + 2HCl = FeCl_2 + H_2$$
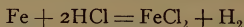
Like most ferrous salts, it is green and prone to oxidize with the formation of the ferric compounds.

FERRIC CHLORIDE—FeCl₃—is made by first forming the ferrous chloride as above, and then adding nitric and hydrochloric acids. The nascent chlorine evolved by the nitro-hydrochloric acid converts the ferrous into ferric chloride, thus :—

$$6FeCl_2 + 6HCl + 2HNO_3 = 6FeCl_3 + N_2O_2 + 4H_2O.$$
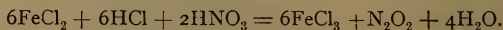
The *liq. ferri chloridi*, U. S. P., is the aqueous solution. This, when diluted with alcohol, forms the *tinct. ferri chloridi*, U. S. P. If citrate of potassium or sodium is added to this tincture, the solution loses its styptic taste, does not affect the teeth, and is not incompatible with solutions containing tannin.

SULPHATES.

FERROUS SULPHATE—FeSO₄—*Copperas, Green Vitriol.*—Prepared: Fe + H₂SO₄ = FeSO₄ + H₂.[235]. Soluble, green crystals efflorescing upon exposure. A cheap and excellent disinfectant, destroying organic matters by abstracting their oxygen. When given in pill form it is first *exsiccated*.

FERRIC SULPHATE—Fe₂(SO₄)₃.—*Tersulphate* is made by adding

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iron and gunpowder into alcohol burning in a dinner-plate and note that the iron burns with bright scintillations, while the gunpowder falls through the flame and is not ignited until the alcohol is burned away to the surface of the plate. ([234]) Make an iron gunpowder by mixing 1 Gm. of reduced iron, 2 Gm. of sulphur and 3 Gm. of KNO₃, and note that it burns as quickly and more brilliantly than ordinary gunpowder.

[235] *Ferrous Salts.* Dissolve iron filings in warm dilute H₂SO₄. Allow a drop of the solution to evaporate on a watch-crystal and note greenish crystals of FeSO₄.

nitrosulphuric acid $(HNO_3 + H_2SO_4)$ to a solution of the ferrous sulphate,[241] thus :—

$$6FeSO_4 + 3H_2SO_4 + 2HNO_3 = Fe_2(SO_4)_3 + N_2O_2 + 4H_2O.$$

Its officinal solution is the *liq. ferri tersulphatis*. *Liq. ferri subsulphatis*, U. S. P., Monsel's Solution, is prepared similarily to the above, except using only half the quantity of sulphuric acid.

FIG. 43.
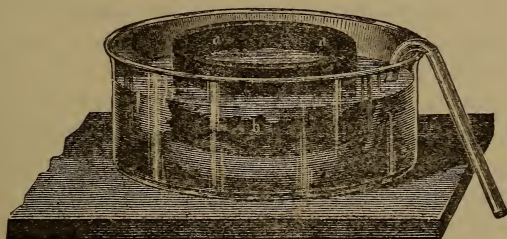
A Dialyzer.

FERROUS HYDRATE—$Fe(HO)_2$—is precipitated on mixing solutions of a hydrate and a ferrous salt,[236] as—

$$FeSO_4 + 2NaHO = Na_2SO_4 + Fe(HO)_2.$$
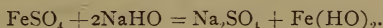
A green precipitate, which soon oxidizes and becomes brown.

FERRIC HYDRATE—$Fe(HO)_3$.—A brownish red, gelatinous mass, precipitated by soluble hydrates from ferric solutions,[242] *e. g.* :—

$$FeCl_3 + 3NH_4HO = 3NH_4Cl + Fe(HO)_3.$$
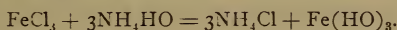
This is the favorite antidote for arsenic, for which purpose it must be freshly prepared and given in large doses. Ferric hydrate

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Ferrous Precipitates. To successive portions of fresh $FeSO_4$ solution add:

[236] KHO = greenish-white precipitate of $Fe(HO)_2$.

[237] Na_2CO_3 = greenish-white precipitate of $FeCO_3$.

[238] NH_4HS = black precipitate of FeS.

[239] $K_4(FeCy_6)$ = pale-blue precipitate of $FeK_2(FeCy_6)$.

[240] K_3FeCy_6 = deep-blue precipitate of $Fe_3(FeCy_6)_2$.

[241] *Ferric Salts.* To a solution of $FeSO_4$ add a few drops each of H_2SO_4 and HNO_3. It turns dark-brown, but on heating changes to a light-red solution of $Fe_2(SO_4)_3$.

Ferric Precipitates. To successive portions of a ferric solution add:

[242] KHO = reddish-brown precipitate of $Fe(HO)_3$.

dissolves freely in a solution of ferric chloride, forming a dark red liquid of a styptic taste.

If this liquid is put in a *dialyzer* (Fig. 43), a vessel with a bottom of parchment or animal membrane, and suspended in water, the chloride passes out through the membrane into the water. When barely enough ferric chloride remains within the dialyzer to hold the ferric hydrate in solution and the styptic taste has disappeared, the liquid is removed and sold under the name of "Dialyzed Iron."

FERRIC NITRATE—$Fe(NO_3)_3$.

Made: $Fe(HO)_3 + 3HNO_3 = 3H_2O + Fe3NO_3$.

Liq. ferri nitratis, U. S. P., is a reddish acid liquid. Used as an astringent, especially in dysentery.

FERROUS IODIDE—FeI_2.—*Prepared:* $Fe + I_2 = FeI_2$.

Sometimes given in pill, but better with syrup, which acts as a preservative as well as a vehicle.

FERROUS CARBONATE—$FeCO_3$—is obtained by adding a soluble (alkaline) carbonate to a ferrous salt,[237] thus :—

$$FeSO_4 + K_2CO_3 = K_2SO_4 + FeCO_3.$$
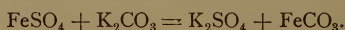
It is insoluble in pure water, but slightly soluble in water containing carbonic acid, as in chalybeate springs. On exposure to the air it turns red from formation of ferric hydrate ; so it is preserved by mixing with sugar and honey, as in the *ferri carbonas saccharatus*, U. S. P.

FERROUS SULPHIDE—FeS [238]—does not *occur* native, but is made by heating together iron filings and flowers of sulphur. Used in the preparation of H_2S. *Iron pyrites* (FeS_2) is a common ore largely used in the manufacture of sulphuric acid and copperas.

SCALE COMPOUNDS OF IRON.—These are ferric salts, mostly with

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[237] $Na_2CO_3 =$ reddish-brown precipitate of $Fe(HO)_3$.

[214] $NH_4HS =$ black precipitate of FeS.

[245] $K_4(FeCy_6) =$ deep-blue precipitate of $Fe_4(FeCy_6)_3$.

[246] $K_3FeCy_6 =$ greenish-brown color.

[247] $K(CyS) =$ deep-red color, discharged by $HgCl_2$.

organic acids. They do not crystallize readily, but are sold as thin scales. Made by evaporating their solutions to a syrupy consistence, poured upon plates, and when dry peeled off in scales. Often other bases, as potassium or ammonium, together with alkaloids, as quinine and strychnine, are incorporated into the compound.

The following are officinal: *Ferri citras, ferri et ammonii citras, ferri et quiniæ citras, ferri et strychniæ citras, ferri et ammonii tartras, ferri et potassii tartras*, and *ferri pyrophosphas.*

Physiological.—Iron is a normal constituent of the body, especially of the blood corpuscles, where it performs an important function, as is shown by the great increase of blood corpuscles and of bodily vigor attending its administration. Many of its salts, especially the ferric salts of the mineral acids, are astringent and hemostatic. Iron is eliminated by various organs, but is mainly discharged by the bowels as sulphide, blackening the fæces.

COBALT.—Its chief ore is a compound with arsenic, sold under the name of *cobalt* or *flystone*, for poisoning flies. Its salts are used in preparing sympathetic ink,[248] for when dried and deprived of water of crystallization, they are a deep blue, but become almost colorless (slightly pinkish) on regaining it. Writing done with a dilute solution of chloride of cobalt is invisible until warmed, when it becomes blue, the color disappearing when the paper is cooled or moistened, especially in a damp air.

NICKEL.—This is a hard, grayish-white metal that does not tarnish in the air.[250] Used to electro-plate instruments made of metals more prone to corrode, and to make cheap coin. Mixed with brass, it forms German silver.

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[248] COBALT. *Sympathetic ink.* Dip a clean pen into a cobalt solution and write on paper (better of pinkish tint). Note that the writing is invisible but becomes deep-blue on carefully drying (avoid scorching) over a lamp, and that it disappears again on cooling by blowing the damp breath on it.

[249] Touch a borax bead to a cobalt solution and heat; note the deep-blue color.

[250] NICKEL. Note the physical properties of the metal and that neither H_2SO_4 nor HCl affect it much, though HNO_3 attacks it vigorously.

MOLYBDENUM, TUNGSTEN, and URANIUM are rare metals and of little importance except that some of their compounds have found a limited application in chemistry and the arts. *Ammonium molybdate* is a valuable test for phosphoric acid and the alkaloids, and phospho-molybdic acid is a reagent for alkaloids. *Sodium tungstate*, Na_2WO_4, has long been used to render fabrics uninflammable, and recently has attained considerable popularity as a test for albumin in urine. *Uranium* salts are used to color glass and impart to it a remarkable fluorescence.

Copper Group

COPPER (*Cuprum*)	Cu	63.4
MERCURY (*Hydrargyrum*)	Hg	200
SILVER (*Argentum*)	Ag	108
GOLD (*Aurum*)	Au	197

Group Characteristics.—Copper and mercury are both *univalent* and *bivalent*, forming two classes of compounds, "*ous*" and "*ic*." Silver being only *univalent* and gold both *univalent* and *trivalent*, they do not strictly belong to this group, yet their chemical behavior is much like that of copper and of mercury. They are all very weakly positive and indifferent to the negative radicals, and hence quite permanent in air and water, and at ordinary temperatures but slowly acted upon by most chemicals.

COPPER [255] is usually found combined with sulphur, etc., but often in the metallic state, especially on the southern shores of Lake Superior. Being found free, it was among the first metals

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Precipitates. To successive portions of a nickel nitrate solution add:

[251] KHO = pale-green precipitate, soluble deep-blue by NH_4 salts.

[252] NH_4HO = pale-green precipitate, soluble deep-blue by NH_4HO.

[253] NH_4HS = black precipitate, slightly soluble in excess of NH_4HS.

[254] *Borax bead* is colored violet while hot and yellowish-brown when cold.

[255] COPPER. *Metal.* Note the physical properties of a bit of copper and that it is attacked very slowly by H_2SO_4 or HCl, but very vigorously by HNO_3, part of which decomposes to oxidize the metal with the evolution of the lower nitrogen oxides and the rest attacks the oxide thus formed.

wrought by man, [256] so the bronze preceded the iron age. Copper is a red malleable metal; an excellent conductor of electricity. It colors the flame green.[257]

CUPRIC SULPHATE—$CuSO_4$—*Blue Vitriol, Blue Stone.*—Obtained as an incidental product from silver refineries, copper mines, etc.; made experimentally by heating copper with strong H_2SO_4. Forms beautiful blue crystals, soluble in water, but insoluble in alcohol. If the crystals are heated they lose their water of crystallization and form a white powder, which becomes blue again upon the addition of water. Hence, used as a test for water in alcohol.[258] Like other salts in which the acidulous radical predominates, cupric sulphate is astringent and coagulates albumen. A prompt emetic, but not used as much as $ZnSO_4$, because if, by chance, it be not all ejected from the stomach, a gastro-enteritis is liable to be set up.

CUPRIC HYDRATE.—$Cu(HO)_2$—is formed as a bluish-white precipitate whenever a soluble copper salt is treated with a soluble hydrate,[259] thus :

$$CuSO_4 + 2KHO = K_2SO_4 + Cu(HO)_2.$$

When heated, even under water, it decomposes—

$$Cu(HO)_2 = CuO + H_2O.$$
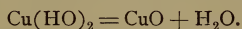
CUPRIC OXIDE—CuO—*Black Oxide.*—*Prepared* by heating copper turnings in air. It gives up its oxygen easily, hence used as an oxidizer in organic analysis.

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[256] *Reduction.* Heat 1 Gm. of verdigris mixed with Na_2CO_3 on a piece of charcoal in the reducing blowpipe flame and note the globules of metallic copper set free.

[257] *Flame.* Dip a platinum wire into a copper solution and note that it colors the flame green.

[258] *Sulphate.* After noting appearance, taste, etc., of a crystal of $CuSO_4$, put it into a test-tube and heat carefully; note that the salt gets amorphous white, losing its water of crystallization. When cool add strong alcohol and shake; note that there is little change. Add to the alcohol a few drops of water and shake, and note the presence of water is shown by the $CuSO_4$ taking again water of crystallization and becoming blue.

[259] *Oxides.* To a solution of $CuSO_4$ add KHO and note a blue precipitate of $Cu(HO)_2$ insoluble in excess of KHO. Boil and note that the $Cu(OH)_2$ decomposes into black cupric oxide and water $(Cu(HO)_2 = CuO + H_2O)$.

CUPROUS OXIDE — Cu_2O—*Suboxide.*—*Made* by boiling the cupric oxide [260] with an oxidizable substance, as glucose (copper tests for glucose), which is oxidized at the expense of the oxygen of the cupric oxide. The precipitate is first yellow (hydrate), but soon becomes a bright red (oxide).

CUPRIC SUBACETATE OR OXYACETATE—sometimes called *verdigris* (green-gray)—is made industrially by exposing plates of copper to the acetic fumes of grape husks, etc. It is likely to be formed whenever fruits containing acetic acid are placed in copper vessels.

Physiological.—Canned fruits, pickles, etc., that have been colored green with copper, and food, especially if acid, that has been cooked or kept in copper vessels, are liable to produce an acute gastro-enteritis. Chronic copper poisoning, so called, is perhaps always due to other substances, as lead or arsenic, and should be treated accordingly.

Antidotes for acute copper poisoning : Encourage vomiting and give albumen (white of egg), which combines with the copper salt to form an insoluble albuminate ; or iron filings, which will precipitate the copper in metallic state.[262]

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[260] Next add some glucose solution and boil; note that the glucose takes part of the oxygen from the black CuO and reduces it to red Cu_2O.

[261] *Hydrates.* Precipitate $Cu(HO)_2$ as in preceding exercise. Then add glucose solution and note that it dissolves the $Cu(HO)_2$, forming a deep-blue solution. Boil, and note that the glucose deoxidizes the $Cu(HO)_2$ and precipitates the yellow $Cu_2(HO)_2$, which rapidly decomposes ($Cu_2(HO)_2 = Cu_2O + H_2O$) into water and red cuprous oxide—the mixture having changed from a deep blue solution through green to a yellow precipitate, which in turn changes from yellow through orange to red. This is the alkali-copper test for glucose, as well as the alkali-glucose test for copper; for when substances react characteristically, each is a test for the other.

Other Tests. Test successive portions of a copper solution as follows :

[262] Dip in a needle or other bright bit of iron, and note it is plated with copper.

[263] Pass H_2S or add NH_4HS and note black precipitate of CuS.

[264] Add NH_4HO and note deep-blue solution of $Cu(NH_3)_2SO_4$.

[265] To the above ammonio-cupric solution, if not too alkaline, add arsenic water and note bright green precipitate of Paris-green ($CuHAsO_3$).

[266] Add $K_4(FeCy_6)$ and a drop of acetic acid and note brownish-red cupric ferrocyanide (Cu_2FeCy_6).

MERCURY is the only metal liquid at ordinary temperatures, and resembles silver in appearance ; hence the names hydrargyrum (water silver) and quicksilver (fluid silver). It is so heavy (specific gravity 13.56) that iron and stone float upon it as corks on

FIG. 44.
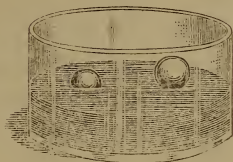
water.   (Fig. 44 represents a marble and a ball of iron floating on mercury.)   It does not tarnish in the air unless contaminated with baser metals ; dissolves most metals,[267] except iron, to form " amalgams." [268]

Uses.—Metallic mercury is used extensively in the refining of silver and gold, in thermometers and other instruments, with tin in silvering mirrors, and in many other branches of the arts. Metallic mercury, rubbed up with various excipients until globules cease to be visible,[269] forms several officinal preparations. Rubbed with chalk, it forms " gray powder," *hydrargyrum cum creta;* with honey of rose and licorice powder, it forms " blue pill," *massa hydrargyri;* and with lard and suet it forms " mercurial ointment," *unguentum hydrargyri.* The therapeutic activity of these preparations is due not to the metallic mercury they contain, but to small quantities of mercurous oxide formed by the oxidation of the finely-divided metal.   So their strength varies with the thorough-

MERCURY. *Metal.*

[267] After noting the physical properties of a small vial of mercury, drop a globule into a dish and add a small shot; note that the mercury and lead combine, forming an *amalgam.*

[268] Drop a globule of mercury into $AgNO_3$ solution and watch the growth of the "*arbor Dianæ,*" a tree-like formation of silver amalgam.

[269] Rub up a few drops of mercury in a mortar with a little lard and note how small the mercury becomes emulsified, the globules soon becoming so small as to be invisible to the naked eye.

ness of the rubbing, the extent of the exposure, and the age of the preparation.

MERCUROUS IODIDE. HgI. Proto-iodide, yellow iodide of mercury, *Hydrargyri iodidum flavum* U. S. P., is made by precipitation [273] from mercurous nitrate and potassium iodide $(Hg(NO_3) + KI = KNO_3 + HgI)$. It was formerly made by rubbing together chemical equivalents, 200 of mercury and 127 of iodine. Some of the blue globules of mercury remaining un-combined gave the yellow HgI a greenish color; hence it was called green-iodide (*hydrargyri iodidum viride*, U. S. P., 1880).

Mercuric Iodide. HgI$_2$. Red iodide, *Hydrargyri iodidum rubrum*, U. S. P., is made by precipitation [270] from mercuric chloride and potassium iodide $(HgCl_2 + 2KI = 2KCl + HgI_2)$. This too was formerly made by rubbing together equivalents of mercury (200) and iodine (254).

The mercuric iodide is dissolved by excess of either the HgCl$_2$ or the KI. In precipitating, mercuric iodide is first yellow, but rapidly becomes red. If some of the dry red powder is placed on a sheet of paper and warmed over a lamp, it changes back to yellow, but on shaking or rubbing, the red is restored. These changes in color are due to changes in crystalline structure.

MERCUROUS NITRATE—HgNO$_3$—is formed when mercury is treated with cold dilute nitric acid.

MERCURIC NITRATE— Hg(NO$_3$)$_2$.—*Acid nitrate of mercury* is formed if the mercury be boiled with strong nitric acid. Like all

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[270] To a drop of mercury in a test-tube add HCl and note that it is *unaffected;* wash out the acid and add HNO$_3$ and note it gradually *dissolved,* especially if warmed.

[271] Mix a dry salt of mercury with twice the amount of Na$_2$CO$_3$ and heat in a dry test-tube. Note that the mercury is *reduced* and sublimes, forming in the cooler part of the tube a deposit of minute globules of metallic mercury.

[272] (Rensch's test.) Boil a strip of bright copper foil in a solution of a salt of mercury; or ([273]) (galvanic test) drop a few drops of the solution on the copper foil and with a bit of zinc or iron (a more positive metal) touch the copper through the fluid. Note in either case a *plating* of metallic mercury on the copper and that the mercury may be distilled off by heating the amalgamated copper in a dry test-tube.

other nitrates, both of the above are soluble. It enters into the *liq. hydrargyri nitratis*, U. S. P., and "citrine ointment," *ung. hydrargyri nitratis*, U. S. P.

MERCUROUS SULPHATE—Hg_2SO_4—is made by digesting sulphuric acid with excess of mercury.

MERCURIC SULPHATE—$HgSO_4$—is made by heating mercury with excess of sulphuric acid. A white, crystalline salt, used in some forms of galvanic batteries. When diluted with water it decomposes into an acid salt, which remains in solution, and a yellow precipitate of oxysulphate, $HgSO_4.2HgO$, called "turpeth mineral," *hydrargyri subsulphas flavus*, U. S. P.

MERCUROUS CHLORIDE—$HgCl$—*Calomel, mild chloride, Hydrargyri Chloridum Mite*, U. S. P.—is made by heating mercurous sulphate with sodium chloride ($Hg_2SO_4 + 2NaCl = Na_2SO_4 + 2HgCl$), when the mercurous chloride sublimes and is condensed in a cool receiver.

Calomel is a white, insoluble powder.[275] Exposed to light it is slowly decomposed ($2HgCl = Hg + HgCl_2$). With aqua regia, and more slowly with other soluble chlorides, it is converted into mercuric chloride. Calomel probably passes through the stomach unaltered, but is converted into the mercurous oxide by the alkaline fluids in the small intestine and slowly absorbed.

MERCURIC CHLORIDE—$HgCl_2$—*Bichloride of Mercury, Corrosive Sublimate*—is prepared by sublimation from a mixture of mercuric sulphate and sodium chloride, thus :—

$$HgSO_4 + 2NaCl = Na_2SO_4 + HgCl_2.$$

It is crystalline and soluble, with a disagreeable styptic taste, and is very poisonous ; much used in antiseptic surgery.

MERCURIC AMMONIUM CHLORIDE—*Ammoniated Mercury, White Precipitate*, U. S. P.—Formed by adding ammonia to a solution

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Mercurous Compounds. Treat successive portions of a solution of a mercurous salt $HgNO_3$ as follows:

[274] Add KI and note the yellow precipitate of HgI.

[275] Add dilute HCl and note the white precipitate of HgCl; filter and heat some of the precipitate in a dry test-tube and note it sublimes.

of mercuric chloride ;[282] mostly used in ointment. It is a double salt of mercury and NH_2, a derivative of ammonium. Its composition is that of NH_4Cl, in which two atoms of H are displaced by one of Hg, forming NH_2HgCl. The ammonio-sulphate of copper, previously described has an analogous composition.

MERCUROUS OXIDE—Hg_2O—*Black Oxide of Mercury*—is made by treating a mercurous salt with a soluble hydrate,[276] as—

$$2HgCl + 2KHO = Hg_2O + 2KCl + H_2O.$$
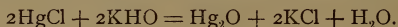
It is seldom used in medicine, except in "black-wash" (*lotio nigra*) made by adding calomel to lime water, and much employed in eczema, chancroids and other parasitic affections.

MERCURIC OXIDE—HgO—*Red or Yellow Oxide.*—When prepared by decomposing mercuric nitrate by heat, it is crystalline and of a red color (*hydrargyri oxidum rubrum*, U. S. P.) ; but when made by precipitating a mercuric solution with a hydrate,[281]

$$HgCl_2 + 2KHO = HgO + 2KCl + H_2O,$$
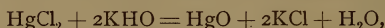
it is an amorphous yellow powder (*hydrargyri oxidum flavum*, U. S. P.). The yellow variety, being amorphous and more finely divided, is less gritty and has greater therapeutic activity.

OLEATE OF MERCURY is made by warming the yellow oxide with oleic acid. A liquid or semi-solid. It is rapidly absorbed when applied to the skin.

MERCUROUS SULPHIDE—Hg_2S—is an unstable compound, which falls as a black precipitate when a mercurous solution is treated with a soluble sulphide.[278]

MERCURIC SULPHIDE—HgS—falls as a black precipitate when a mercuric solution is treated with a soluble sulphide.[283] It is found in nature in crystalline masses called *cinnabar*. By certain processes it may be obtained as a deep-red crystalline powder, called *vermilion*.

Tests.—These consist in adding, to the suspected liquid, solu-

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[276] Add KHO and note black precipitate of Hg_2O.

[277] Add NH_4HO and note black precipitate of mercurous ammonium chloride (NH_2Hg_2)Cl.

[278] Pass H_2S and note black precipitate of Hg_2S.

tions of salts containing radicals capable of uniting with mercury and of forming precipitates of the foregoing insoluble compounds. But the *galvanic test*[273] is perhaps the best for clinical purposes. On a gold or copper coin put a drop of the suspected solution acidulated with HCl, and touch the coin through the drop of fluid with a piece of baser metal, as a knife blade. Mercury, if present, will be deposited on the coin in a silvery film.

Physiological.—Acute poisoning occurs from swallowing a single large dose of some of the mercuric compounds, especially corrosive sublimate. The minimum fatal dose of corrosive sublimate is three grains; of white precipitate and turpeth mineral forty grains. Children tolerate mercury much better in proportion to their age than adults. The symptoms are those of severe gastroenteric irritation. Give albumin, with which it forms an insoluble compound. Iron filings also act as a chemical antidote by decomposing the salt, taking the acidulous radical and depositing the mercury in the metallic state.

Chronic poisoning is often called, from its most prominent symptom, *salivation* or *ptyalism*. It usually occurs from small, but often repeated doses of the mercurous preparations, as blue pill, calomel, etc. One of the first *symptoms* is a delicate red line along the margin of the gums; then comes a metallic taste, abdominal pains, nausea, vomiting, dysenteric diarrhœa, profuse flow of saliva, fetid breath, fever, emaciation, and paralysis.

Mercuric Compounds. To successive portions (5 Cc.) of a solution of mercuric chloride add:

[279] KI and note precipitate, first yellow and then red, of HgI_2. ([280]) Dissolve this with excess of KI and make strongly alkaline with KHO, forming the solution of potassium-mercuric iodide, called Nessler's reagent. Add a drop of this reagent to the most dilute solution of an ammonium salt and note the brown precipitate of dimercuric-ammonium iodide $(NHg_2)I$.

[281] KHO and note the yellow precipitate of HgO.

[282] NH_4HO and note the white precipitate of mercuric-ammonium chloride, $(NH_2Hg)Cl$.

[283] H_2S and note black precipitate of HgS.

[284] Albumen (white of egg) and note white precipitate of mercuric albuminate.

Sphacelation of the mouth and lips sometimes occurs. The *treatment* is to stop the ingestion of poison, and give some astringent, as tannin.

SILVER *occurs* free, but often as a sulphide associated with lead in galena. A white, malleable, ductile metal, capable of a high polish; best known conductor of electricity; dissolved readily by nitric,[285] but not by hydrochloric or sulphuric acid, except by the aid of heat; does not tarnish in air unless ozone or H_2S be present.[290]

Used to plate mirrors and articles made of the more corrodible metals; alloyed with copper as coin; for tubes, sutures, etc., in surgery, for it does not corrode and irritate the tissues.

SILVER NITRATE—$AgNO_3$—*Argenti Nitras*, U. S. P., *Lunar Caustic*. *Made* by the action of nitric acid on silver. If coin silver is used, the solution is blue, from the presence of copper. Silver nitrate is a crystalline salt, very soluble. Its taste is acrid, and in large doses it acts as corrosive poison, destroying the tissues by coagulating their albumin. For use as a cautery it is fused and moulded into sticks.

SILVER OXIDE—Ag_2O—is precipitated as a brown powder on treating a solution of silver nitrate with caustic potash[290] or soda

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[285] SILVER. *Metal.* After noting the physical properties of the silver in a dime, dissolve it in HNO_3 with gentle heat, avoiding the inhalation of the fumes. Add HCl until all the silver is precipitated as AgCl, and filter. Show that the copper is retained in the (blue) filtrate by a few of the tests already given for that element. Wash the precipitate (AgCl) and add to it, in a dish, a little dilute H_2SO_4 and a bit of zinc: allow it to stand until the next day or next exercise, when the silver will be observed to have separated out into a dark spongy mass, and may be fused into a bright button.

[286] Heat with the blow-pipe a little $AgNO_3$ or charcoal and note that it is reduced to a metallic button.

[287] Provide two bits of white cloth blackened with indelible (silver) ink and boil one with dilute HNO_3 and the other with KCy and note that in each case the precipitated silver is dissolved out and the black stain removed.

Insoluble Compounds. To successive portions of $AgNO_3$ solution add:

[288] KCy and note white precipitate of AgCy soluble in excess of KCy.

[289] K_2CrO_4 and note red precipitate of Ag_2CrO_4.

[290] H_2S or NH_2HS and note black precipitate of Ag_2S.

[291] KHO and note brown precipitate of Ag_2O.

($2AgNO_3 + 2KHO = 2KNO_3 + Ag_2O + H_2O$). Slightly soluble in water. The other salts of silver are insoluble, and made by precipitating a solution of silver nitrate with a solution containing the appropriate radical.

SILVER CYANIDE.—AgCN, may be made by mixing solutions of silver nitrate[285] and potassium cyanide ($AgNO_3 + KCN = AgCN + KNO_3$). A white precipitate soluble in ammonium hydrate and sodium hyposulphite, and in excess of potassium cyanide as in the silver-plating bath. It is unaffected by light.

SILVER CHLORIDE—AgCl.—A white, curdy precipitate,[292] insoluble in acids, but freely soluble in ammonium hydrate, may be made by adding a chloride to a silver solution, thus :—

$$AgNO_3 + HCl = AgCl + HNO_3.$$

SILVER BROMIDE—AgBr is a similar precipitate,[293] except that it is yellowish-white and much less readily soluble in ammonium hydrate, and is made by adding a bromide to a silver solution, thus :—

$$AgNO_3 + KBr = AgBr + KNO_3.$$

SILVER IODIDE is precipitated[292] on mixing an iodide solution and a silver solution ($AgNO_3 + KI = AgI + KNO_3$) and is yellow and insoluble in ammonium hydrate.

Effects of Light.—Light decomposes salts of silver, especially if organic matter be present, depositing metallic silver in a fine, black powder, hence their uses in photography, and in making indelible inks, hair dyes, etc. The black stain of silver on the hands or clothes[287] may be removed by potassium cyanide or by applying tincture of iodine and washing in ammonia-water. When persons have taken silver salts for a long time, it sometimes occurs that the tissues, especially the skin, are permanently darkened. This is due to the decomposition of the silver salt under the influence of organic matter and light.

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[292] HCl and note white precipitate of AgCl, soluble in NH_4HO.

[293] KBr and note yellowish-white precipitate of AgBr, slightly soluble in NH_4HO.

[294] KI and note yellow precipitate of AgI, insoluble in NH_4HO.

[295] Repeat tests 292, 293, 294, but instead of NH_4HO add sodium hyposulphite and note how readily all three precipitates dissolve.

Photographic "sensitized" plates, papers, etc., are generally coated on one side with a film of collodion, gelatine or albumen in which is precipitated in the dark, a fine deposit or "emulsion" of silver chloride, bromide or iodide. On the least exposure to light, and in proportion to such exposure, the molecules of these silver salts are so disturbed that when subjected to the action of a reducing agent ("developer") in the dark-room they decompose, depositing black metallic silver. As soon as the plate is sufficiently developed, it is dropped into a solution of sodium hyposulphite, which dissolves out all the unreduced silver salt[293] but not the black deposit of metallic silver, and the plate is said to be "fixed" as there is no more silver salt in it to blacken it further.

Poisoning occurs mostly from swallowing the nitrate, which is the only soluble silver salt. It is a severe corrosive poison, destroying the tissues by coagulating their albumin. Its best antidote is a soluble chloride, as common salt, which forms the insoluble silver chloride. Albumin is also a good antidote.

GOLD *occurs* widely, but sparingly distributed ; always free, mixed with sand and quartz, from which it is separated by agitation with water or by dissolving it out with mercury. It is a soft, bright, yellow metal ; so malleable that it may be beaten into sheets (gold leaf) less than one two-hundred-thousandth of an inch in thickness. These transmit green light.[296] For coinage and general use gold is usually hardened by the addition of copper or silver, the amount of which is indicated by the term *carat fine*. Thus, pure gold is twenty-four carat, and eighteen, sixteen, and twelve carat signify so many twenty-fourths of pure gold.

Gold does not tarnish in the air ; is unaffected by alkalies or any single acid,[297] but nitro-muriatic acid (aqua regia) easily dissolves it,[298] forming *auric* chloride, a salt that is easily decom-

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[296] GOLD. *Metal.* After noting the physical properties of a sheet of gold-leaf, lay it between two glass slides, hold it before a strong light and note that it is translucent and green. ([297]) Divide it in two portions, and drop one into HNO_3 and the other into HCl in separate beakers. Note that neither acid affects the gold. ([298]) Pour the contents of one beaker into the other and note that the gold dissolves.

posed by heat, light, organic matter and various chemicals,[298] with the deposition of metallic gold in fine powder as in "toning" photographic prints. With stannous chloride it yields a beautiful precipitate (purple of Cassius) used in ornamenting porcelain and glassware.

The "*Auri et Sodii Chloridum*," U. S. P. ($AuCl_3NaCl$, is sometimes given in doses of .005 Gm. ($\frac{1}{16}$ gr.) as a nerve tonic and stimulant in functional impotence and in some of the "gold cures" for inebriety.

PLATINUM *occurs* free, associated with the allied metals, palladium, rhodium, ruthenium, osmium and iridium. Owing to its scarcity it is almost as costly as gold. Resembles silver in appearance ;[301] can be melted only with very great difficulty, and very few substances corrode it ; hence it is used to make vessels that are to be exposed to very high heat or to contain corrosive chemicals. Platinum wire is also used in flame testing.

Platinum readily dissolves in nitro-muriatic acid, forming *platinic chloride*, $PtCl_4$, a valuable reagent for potassium, ammonium and alkaloids.[302]

The other members of this group are rare elements found in small quantities in certain platinum ores. Iridium is used in the hard tip of gold pens and is often added to platinum to increase its hardness and resistance to chemical agents. Osmium and palladium compounds are sometimes used as chemical reagents, and osmic acid (osmic anhydride, OsO_4) is much employed as a stain in histology.

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[299] To a gold solution ($AuCl_3$) in a test-tube add $FeSO_4$ and set aside; a yellow lustrous deposit of gold is precipitated on the inside.

[300] To some $AuCl_3$ solution add a bit of tin-foil and note the formation of the "purple of Cassius."

[301] PLATINUM. *Metal.* Note the physical properties of the metal by examining the mounted platinum wire kept on the desk.

[302] *Compound.* To a few drops of a platinum solution add a drop of potassium or ammonium solution and note the creamy precipitate of K_2PtCl_6 or $(NH_4)_2PtCl_6$.

[303] To a platinum solution add a few drops of potassium iodide, and note the dark-red color, giving place to a black precipitate on heating.

TABLE.—TO DETERMINE BY SYSTEMATIC ANALYSIS THE METALLIC RADICAL OF A SALT IN AQUEOUS OR SLIGHTLY ACID SOLUTION.

Add hydrochloric acid.

If HCl gave no precipitate the metal is still in the liquid; pass H_2S through the solution.			
Precipitate Hg(ous) Pb Ag, Collect, wash, and add NH_4HO. Hg ppt., blackened. Pb ppt., still white. Ag ppt., dissolved. Sb and Bi may also be precipitated by HCl, but are dissolved on adding more HCl.	If H_2S gave no precipitate add NH_4Cl, NH_4HO and NH_4HS.		
	Precipitate Cd Cu Hg(ic) Pb Bi As Sb Sn Au Pt, Collect, wash, add NH_4HS. Insoluble. Cd, yellow Cu } black. Hg(ic) Pb Bi Soluble. As(ous & ic) Sn(ic) } yellow. Sb, orange. Sn(ous) Au } black. Pt Apply special tests for each to the original solution. For these, see the previous pages.	If NH_4HS gave no precipitate add $(NH_4)_2CO_3$.	
		Precipitate Zn Mn CO Ni Al Fe Cr. Zn Al } white. Cr, green. Mn, skin-tint. Ni Co } black. Fe Test specially for each in original solution. See previous pages.	If $(NH_4)_2CO_3$ gave no precipitate add $(NH_4)_2HAsO_4$.
		Precipitate Ba Sr Ca Collect, wash, dissolve in $HC_2H_3O_2$, add K_2CrO_4. Ppt. Ba. Sol. Sr Ca. Add dil. H_2SO_4. Ppt. Sol. Sr. Ca.	Ppt. Mg. If no precipitate, test original solution in flame on loop of Pt wire. Li, crimson. Na, yellow. K, violet. If neither, test orig. sol. for NH_4.

TABLE.—TO DETERMINE THE ACIDULOUS (NEGATIVE) RADICAL OF AN ORDINARY SALT IN AQUEOUS SOLUTION, POUR SMALL PORTIONS INTO FIVE TEST-TUBES, THE SOLUTION RENDERED NEUTRAL, IF NECESSARY, BY AMMONIA. THEN ADD TO EACH RESPECTIVELY A FEW DROPS OF SULPHURIC ACID, BARIUM CHLORIDE, CALCIUM CHLORIDE, SILVER NITRATE, AND FERRIC CHLORIDE. INTERPRET THEIR EFFECTS ACCORDING TO THE FOLLOWING TABLE:

	H_2SO_4 decomposes	$BaCl_2$ precipitates	$CaCl_2$ precipitates	$AgNO_3$ precipitates	$FeCl_3$ precipitates	Not precipitated.
Sulphites Sulphides Carbonates	With effervescence of H_2S and SO_2, known by smell, and CO_2 having no noticeable odor.	(All white.) Sulphates, insol. in HCl. Sulphites } Effervesce Carbonates } with acids. Citrates } Char when Tartrates } heated on platinum foil Borates. Oxalates. Phosphates.	(All white.) Sulphates, sol. in much water. Borates } soluble Carbonates } in Citrates } NH_4Cl. Phosphates. Oxalates. Sulphites. Tartrates. All sol. in acetic acid, except oxalate and tartrate. All sol. in HCl, except much sulphate. Citrate and tartrate char when heated on platinum foil. Carbonate and sulphite effervesce with acids, evolving H_2S and SO_2.	Borates Carbonates Chlorates Citrates Cyanides Oxalates Sulphates Tartrates } white. Bromides } yellowish-white. Phosphates } yellow. Iodides Sulphides, black. All soluble in dilute nitric acid, except chloride, bromide, iodide, cyanide, and sulphide.	Phosphates } yellowish-white. Borates, yellowish. Oxalates, yellow. Carbonates, reddish. Acetates, red if neutral. Sulphides, black.	Nitrates. Chlorates. Apply special tests (see previous pages).
Cyanides	with odor of HCN.					
Acetates	with odor of acetic acid, especially if warmed.					

TABLE.—THE SOLUBILITY OR INSOLUBILITY OF SALTS IN WATER.

Much time may be saved by not applying special tests to an aqueous solution for salts known to be insoluble in water.

S, soluble; Ss, slightly soluble; I, insoluble; ?, unknown or does not exist.

	Acetate	Arseniate	Arsenite	Carbonate	Chloride	Citrate	Chromate	Cyanide	Hydrate	Iodide	Nitrate	Oxalate	Oxide	Phosphate	Sulphate	Sulphide	Sulphite	Tartrate
Aluminium	S	I	I	I	S	Ss	I	?	I	S	S	I	I	I	S	I	I	S
Ammonium	S	S	S	S	S	S	S	S	S	S	S	S	?	I	S	S	S	S
Antimony	S	I	I	?	S	?	?	?	I	I	?	I	I	I	S	I	I	I
Barium	S	I	I	I	S	Ss	I	S	S	S	S	I	S	I	I	I	I	Ss
Bismuth	S	I	I	I	S	Ss	I	S	I	I	S	I	I	I	I	I	Ss	I
Cadmium	S	I	I	I	S	S	I	I	I	S	S	I	I	I	S	I	I	Ss
Calcium	S	I	I	I	S	S	S	S	Ss	S	S	Ss	I	I	Ss	I	S	Ss
Chromium	S	I	I	I	S	S	I	I	I	S	S	I	I	I	S	I	I	S
Cobalt	S	I	I	I	S	S	I	I	I	S	S	I	I	I	S	I	S	S
Copper	S	I	I	I	S	S	I	I	I	?	S	I	I	I	S	I	Ss	S
Ferric	S	I	I	I	S	S	I	?	I	?	S	I	I	I	S	I	?	S
Ferrous	?	I	?	I	S	S	?	I	Ss	S	S	Ss	I	I	S	I	Ss	I
Gold	?	?	?	?	S	?	?	?	?	?	?	?	?	?	?	?	?	?
Lead	S	I	I	I	Ss	Ss	I	I	I	S	S	I	I	I	Ss	I	S	I
Magnesium	S	I	I	I	S	S	Ss	S	I	S	S	Ss	I	I	S	I	S	S
Manganese	S	I	I	I	S	S	I	I	I	S	S	Ss	I	I	S	I	S	I
Mercuric	Ss	I	I	I	S	S	Ss	I	I	S	S	I	I	I	S	I	I	Ss
Mercurous	Ss	S	?	I	Ss	Ss	S	I	?	I	S	I	I	I	Ss	I	I	S
Nickel	S	I	I	I	S	S	I	I	I	S	S	I	I	I	S	I	S	S
Platinum	?	I	I	I	S	?	?	S	?	S	S	?	I	I	S	I	?	I
Potassium	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Silver	Ss	S	S	I	S	Ss	I	I	?	I	S	I	I	I	Ss	I	I	Ss
Sodium	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Stannic	S	?	I	I	S	Ss	I	I	I	S	S	I	I	I	S	I	S	S
Stannous	S	I	I	S	S	?	I	?	I	S	S	S	I	I	S	I	S	S
Strontium	S	I	I	I	S	S	I	S	S	S	S	I	I	I	Ss	I	S	Ss
Zinc	S	I	I	I	S	Ss	I	I	I	S	S	I	S	I	S	I	Ss	Ss

PART II.—ORGANIC CHEMISTRY.

ORGANIC CHEMISTRY is the *chemistry* of the compounds of carbon, and this chapter may be considered a resumption of the study of that element. The name " organic " is a relic of an old misconception.

Centuries ago it was observed that substances produced by, and composing living organisms differed remarkably from those of mineral origin ; they were subject to decay, fermentation and putrefaction, and when burned left no residue except such mineral matters as were incidentally incorporated. Having never seen them produced except under the influence of organized life, the older observers assumed that they could not be formed otherwise, and called them "organic." But in 1828, Woehler made urea from ammonium cyanate, and soon after Kolbe made acetic acid from materials as plainly mineral. Since that time artificial products, many of them unknown in nature, have become so numerous and complex that it now seems possible to duplicate artificially any organic substance, especially if its chemical constitution be known. However, chemistry has not, and probably never will, produce an *organized* body, *i. e.*, one having an anatomical, cellular structure. Such structures must live and grow ; their study is the office of physiological chemistry.

Carbon is the constant and characteristic constituent of all the organic compounds, and is responsible for their vast number and great complexity. Though carbon forms compounds of infinite number and extreme complexity, it is with the aid of a very few other elements, viz : hydrogen, oxygen, nitrogen, and occasionally sulphur, phosphorus and iron, sometimes others ; but the larger number of even the artificial compounds contain only the above-named elements. This is due to the fact that the carbon atoms possess, in the highest degree, the power of *combining with*

each other and interchanging valences, forming groups or chains around which the other elements are arranged. But for this power carbon could form only one saturated compound with hydrogen, CH_4. Carbon being quadrivalent, the compounds C_2H_6 and C_3H_8 would be unsaturated. Experiment, however, proves that they are saturated compounds. The .explanation is that the carbon atoms combine with each other, mutually neutralizing one or more valences, thus :—

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H; \quad H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H; \quad H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H.$$
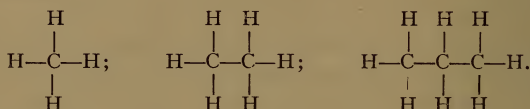
It will be observed that these formulæ have a common difference of CH_2. They are said to form a *homologous series.* When the carbon remains the same but the hydrogen differs by H_2, the series is said to be *isologous.*

In the following examples each vertical column represents a homologous, each horizontal line an isologous series :—

C H_4—Methane	C H_2—Methene	C —Methine
C_2H_6—Ethane	C_2H_4—Ethene	C_2H_2—Ethine
C_3H_8—Tritane	C_3H_6—Tritene	C_3H_4—Tritine
C_4H_{10}—Tetrane	C_4H_8—Tetrene	C_4H_6—Tetrine
C_5H_{12}—Pentane	C_5H_{10}—Pentene	C_5H_8—Pentine.

Without this arrangement in series, it would be almost impossible to remember the composition of organic substances.

In systematic works on organic chemistry, these series form the basis of classification ; but as this would necessitate mentioning thousands of bodies of no medical interest, it would be impracticable in a work like this ; and after all, no system of classification yet devised is perfectly satisfactory. We shall therefore adopt the following :

Hydrocarbons and their derivatives.   *Organic acids.*
Alcohols.   *Carbohydrates* (sugars and starches).
Ethers (including oils and fats).   *Glucosides.*
Aldehydes.   *Ammonium substitution products.*
                    Natural alkaloids.

The ULTIMATE ANALYSIS of a carbon compound resolves itself into the determination of the presence and quantity of carbon, hydrogen and oxygen, and since many of these compounds, especially those from the animal and vegetable kingdom, contain nitrogen, and at times also sulphur, phosphorus and iron, their presence must also be proven, and quantity estimated.

The determination of the quantity of oxygen is so difficult, and the process so complicated, that it is usually computed by difference after the other elements have been quantitatively calculated.

Determination of carbon.—Carbon is known to be present when a substance chars on igniting it away from air. The quantity of carbon is estimated by combustion, whereby the carbon unites with oxygen to form carbon dioxide—CO_2. In the same experiment the hydrogen unites with oxygen to form water H_2O, and we thus estimate quantitatively the hydrogen present.[304]

Determination of Nitrogen.—Heat the substance in a test-tube. A pungent odor like that of burnt feathers indicates the presence of nitrogen, as does the odor of ammonia when a fixed alkali is also added.[305]

The amount of nitrogen is estimated by collecting and measuring the ammonia.

Determination of Sulphur.—To the substance in a test-tube add solid KHO, which, with the sulphur, yields potassium

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[304] Mix the substance under examination with copper oxide and heat in a hard-glass tube. Draw the products of this combustion through a series of tubes containing dried, granulated calcium chloride, which will absorb the water, and through a second vessel (a Liebig bulb) containing potassium hydrate, which absorbs the carbon dioxide. The vessels containing the calcium chloride and potassium hydrate are each separately weighed, before and after the combustion, and the difference in weight represents the amount of water and carbon-dioxide present. From these weights the carbon and hydrogen are readily estimated.

[305] To the substance to be examined in a test-tube add some metallic potassium, and heat. Potassium cyanide is formed. Add water, and filter. To the filtrate add ferrous sulphate containing a little ferric salt, and then several drops of KHO. Heat again and add HCl in excess. A precipitate of Prussian-blue indicates nitrogen.

sulphide.   Dissolve in a little water, a drop of which, on a clean piece of silver, makes a black stain of Ag_2S.

Determination of Phosphorus.—(Method of Carius.)   Oxidize the substance by heating it with nitric acid in a sealed tube.   If phosphorus be present phosphoric acid is formed, and may be recognized by the tests already given for the phosphates.

Determination of Chlorine, Bromine and Iodine..—They may be detected by heating the substance with lime, dissolving in water, acidifying with nitric acid and testing the filtrate by the appropriate tests.[307]

MOLECULAR FORMULÆ.—The analysis of a substance shows only its percentage composition ; the formula must be deduced by dividing the percentage of each element by its atomic weight to show how many atoms it represents and then making the formula to correspond to these ratios.   For instance, acetic acid shows this percentage composition—Carbon, 40.00 ; Hydrogen, 6.66 ; Oxygen, 53.34.

$$40.00 \div 12 = 3.33 \text{ atoms of Carbon.}$$
$$6.66 \div 1 = 6.66 \text{ atoms of Hydrogen,}$$
$$53.34 \div 16 = 3.33 \text{ atoms of Oxygen.}$$

These ratios are seen to bear to each other the proportion of one of carbon, two of hydrogen, and one of oxygen ; hence the formula, CH_2O.   But formaldehyde, lactic acid and several other substances show the same percentage composition.   We would thus be still left in doubt as to the correct formula of each were it not for a knowledge of their respective molecular weights, as shown by their "vapor densities."   Since we know that 30 is the molecular weight of formaldehyde ; 60 of acetic acid and 90 of lactic acid ; and that CH_2O (12 + 2 + 16) represents a molecular

[306] Add KHO to lead-acetate solution until the precipitate first formed is redissolved.   In this boil the sulphurized organic substances (*e. g.*, albumin) and note the blackening by the PbS formed.

[307] A delicate test is to place some cupric oxide on a platinum wire, and keep it in the flame until it appears colorless.   Place a little of the substance under examination on the cupric oxide, and heat in the non-luminous gas flame, when the presence of either chlorine or bromine will be indicated by an intense greenish-blue color.

weight of 30, we see that CH_2O = formaldehyde ; $C_2H_4O_2$ = acetic acid, and $C_3H_6O_3$ = lactic acid.

The above are *empirical* formulæ since they show only the number and kind of atoms composing the molecule. The *rational* formula aims to show also the constitution of the molecule, the arrangement of its atoms into radicals. Thus in acetic acid one atom of the hydrogen plays the part of the positive radical ; while the other atoms of the molecule form its negative radical ; so the rational formula is $HC_2H_3O_2$.

Isomerism.—Two or more substances are said to be isomeric when they have the same empirical but different rational formulæ, differ in chemical properties and are hence distinct substances, *e. g.*, aldehyde, C_2H_4O or CH_3–CO–H ; and ethylene oxide, C_2H_4O or CH_2–O–CH_2. Substances whose formulæ are simple multiples of each other are said to be *polymeric*, *e. g.*, formaldehyde (CH_2O), acetic acid ($C_2H_4O_2$) and lactic acid ($C_3H_6O_3$). When elements manifest this same quality it is called *allotropism ;* of which we have already noticed instances in coal, graphite and diamond, and in ordinary oxygen and ozone.

Hydrocarbons.

Hydrocarbons are compounds of carbon with hydrogen only. They are exceedingly numerous and are regarded as derived from CH_4 in homologous and isologous series. The following table shows the usual classification :

Series 1 Gen. Formula $CnH2n+2$. Valence	Radicles Gen. Formula $CnH2n+1$. Valence	Series 2 Gen. Formula $CnH2n$. Valence	Radicles Gen. Formula $CnH2n-1$. Valence	Series 3 Gen. Formula $CnH2n-2$. Valence	Series 4 Gen. Formula $CnH2n-4$.		
O	I	II	III	IV			
Methane. CH_4	Methyl. CH_3	Methene. CH_2	Methenyl. CH	Methine. C			
Ethane. C_2H_6	Ethyl. C_2H_5	Ethene. C_2H_4	Ethenyl. C_2H_3	Ethine. C_2H_2	Ethone. C_2		
Tritane. C_3H_8	Trityl. C_3H_7	Tritene. C_3H_6	Tritenyl. C_3H_5	Tritine. C_3H_4	Tritone. C_3H_2	Tritune. C_3	
Tetrane. C_4H_{10}	Tetryl. C_4H_9	Tetrene. C_4H_8	Tetrenyl. C_4H_7	Tetrine. C_4H_6	Tetrone. C_4H_4	Tetrune. C_4H_2	
Pentane. C_5H_{12}	Pentyl. C_5H_{11}	Pentene. C_5H_{10}	Pentenyl. C_5H_9	Pentine. C_5H_8	Pentone. C_5H_6	Pentune. C_5H_4	
Hexane. C_6H_{14}	Hexyl. C_6H_{13}	Hexene. C_6H_{12}	Hexenyl. C_6H_{11}	Hexine. C_6H_{10}	Hexone. C_6H_8	Hexune. C_6H_6	
etc.	etc.	etc.	etc.	etc.			

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The nomenclature is systematic, but has never been fully adopted. The root of each name is from a Greek numeral and indicates its position in homologous series, while the final vowel indicates its position in isologous series. By successive abstractions of an atom of hydrogen are formed several series of organic radicles, the valences of which depend on the number of atoms abstracted, and thus increase in isologous series. They are given the general termination of "-yl." Being positive, these radicles combine with negative radicles, just as do K, Na or NH_4, and form analogous compounds.

METHANE SERIES, sometimes called the *Paraffins* (*parum*, too little and *affinis*, having affinity) on account of their lack of affinity for chemical reagents, is a class of hydrocarbons derived in homologous series from CH_4. Being fully saturated, they are very stable and indifferent to chemical reagents, unaffected usually by either acids or alkalies. The natural, crude *Petroleum* is a mixture of mainly these various hydrocarbons [308] as far down as the sixteenth ($C_{16}H_{34}$). On account of their boiling-points varying with their molecular weights, they can be more or less completely separated by fractional distillation, those having the lightest molecules passing over first. As all the lighter ones are liable to give off vapors that when mixed with air are explosive, it is forbidden in most states to sell, for use in ordinary lamps, an oil that "flashes" below 100 F., or itself ignites below 300 F. Of

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[308] Cymogene, boils about 32° F.; used in ice-machines.
Rhigolene, boils about 65° F.; as a spray for local anæsthesia.
Petroleum Ether, boils about 100° F.; used as a solvent and for "air-gas."
Gasolene, boils about 120° F; used as a solvent and for "air-gas."
Naphtha, A, B and C, boils 180 to 300° F.; used as a solvent for fats, etc.
Benzine, boils about 150° F.; used as solvent in varnishes and paints.
Kerosene, boils about 350° F.; used in ordinary lamps.
Mineral Sperm oil, boils about 425° F.; used for lubricating machinery.
Lubricating oil, boils about 575° F.; used for lubricating machinery.
Petrolatum, U. S. P., used in ointments, etc.
Paraffine, used in candles.

[309] Into a large test-tube pour about 20 Cc. of cheap kerosene, insert a thermometer and a bent glass tube. Apply a heat so gently that the temperature rises only about a degree a minute. At frequent intervals blow through the glass tube and make a foam on the surface of the oil and apply a flame to the mouth of the test-tube. When the flame flashes down the tube note the reading of the thermometer and regard that as the "flashing-point."

the commercially separated products the Pharmacopœia recognizes as officinal *Benzine* or petroleum ether, a colorless, volatile liquid ; *Petrolatum Liquidum*, a tasteless, oily liquid, called also albolene ; *Petrolatum Molle*, the soft vaseline, and *Petrolatum Spissum*, the harder vaseline.

Methane (CH_4) is a light, colorless gas, occurring in illuminating gas formed from the destructive distillation of coal ; in coal mines as "fire damp," where it often causes frightful explosions ; from decomposition of vegetable matter under water, where as "marsh-gas" it may be seen bubbling up, especially when the mud is stirred ; in natural gas, of which it constitutes over 90 per cent. CH_4 is the starting point for the synthetical production of many other organic compounds, and may itself be made artificially from ethine (acetylene), which is made from the minerals, calcium carbide and water.[310]

Ethane (C_2H_6), *Tritane* or *propane* (C_3H_8), and *Tetrane* or *butane* (C_4H_{10}), escape when crude petroleum is heated. These gases are collected, condensed into a liquid, and sold as cymogene for ice making.

METHENE SERIES.—These were formerly called "olefins," because the first member, *Ethene* (C_2H_4), happens to form an oily liquid with chlorine, and was named "olefiant gas." Ethene is formed in the destructive distillation of coal, and is the most valuable constituent of illuminating gas, where it is called "heavy carburetted hydrogen." Being unsaturated the olefins are readily attacked by reagents, especially the acids.

ETHINE SERIES.—These too are unsaturated ; they act as bivalent or quadrivalent radicles.

Ethine or acetylene (C_2H_2) is the most important member and enjoys the distinction of being one of the few, if not the only, hydrocarbon made by the direct union of its elements. It may be produced by the electric arc between carbons in an atmosphere

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[310] Heat in a test-tube a mixture of 4 parts of sodium acetate, 4 parts of NaHO and 6 parts of lime; collect the gas; it is methane.

of hydrogen.   It is now made industrially as an illuminant, from calcium carbide [311] and water; thus, $CaC_2 + 2H_2O = Ca(HO)_2 + C_2H_2$.   It is very rich in carbon (92.3 per cent.) and burns with a very pure white flame of dazzling brilliancy.

TRITONE SERIES OR TERPENES.   These· are unsaturated and either univalent or bivalent and combine readily with the negative radicals.   The series begins with Tritone (C_3H_2), but it is the eighth member, Decone or *Terpene* ($C_{10}H_{16}$) that possesses most medical interest, as this formula represents the composition (isomeric) of most of the volatile or essential oils, such as those of lemon, orange, cloves, pepper, lavender, bergamot, etc.

Volatile oils are found in plants, especially in the flowers, of which they are usually the odorous essences (hence called also essential oils).   They are obtained by distillation, are very slightly soluble in water (aquæ), but quite soluble in alcohol (spiritus).   A cologne is an alcoholic solution of an assortment of volatile oils.

Turpentine (oleum terebinthinæ, U. S. P. obtained from Pinus Australis) is the most important of the volatile oils; obtained as a resinous juice from various coniferæ, and may be taken as a type of the class.   It is a thin colorless liquid, a valuable solvent of oils and resins; absorbs oxygen and stores it up as ozone, gaining thereby oxidizing, antiseptic and disinfectant properties.   By the action of concentrated sulphuric acid, turpentine is changed into *terebene* ($C_{10}H_{16}$), a valuable remedy for bronchitis and flatulence.

Resins and Camphors.   On exposure to air the terpenes oxidize with the production of resins and camphors, whose formula is $C_{10}H_{16}O$.

Resins are a numerous class, many of which are true acids or mixtures of acids.   They are soluble in alcohol but insoluble in water except by the intervention of an alkali with which they will

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[311] *Calcium Carbide*, CaC_2.   The manufacture of this recently discovered article is remarkably simple and cheap.   When a mixture of lime and coke are placed in the electric furnace they fuse into a dark gray crystalline mass on which the heat has no further effect.   This calcium carbide is packed for the market in sealed cans to protect it from the water of the air.

unite to form soluble soaps. The official resin (resina, U. S. P.) is formed by the oxidation of turpentine as it exudes from the pine trees.

Solutions of shellac, mastic, copal and others are used as varnishes. In the natural state, resins are usually mixed with other substances. Mixed with volatile oils they form oleo-resins and balsams, *e. g.*, benzoin, tolu and balsam of Peru; and with gums, gum resins, *e. g.*, ammoniac, myrrh and asafœtida.

Camphors, sometimes called stearoptens.—These are white, crystalline, volatile solids of an agreeable, pungent odor; slightly soluble in water (aqua camphoræ), freely soluble in alcohol (tinctura camphoræ) ether and oils.

Common Camphor is derived from the leaves and branches of the camphor laurel of China and Japan. It is much used; internally, as a stimulant, diaphoretic, carminative and expectorant, and externally, as an antiseptic and analgesic.

Monobromated Camphor, $C_{10}H_{15}BrO$, is made by adding bromine to a solution of camphor in chloroform, the bromine displacing one atom of hydrogen. It is more sedative than ordinary camphor.

Menthol is the camphor of oil of peppermint, and has its odor. It is much more analgesic than common camphor.

Thymol is the camphor of oil of thyme and of horsemint. It is a stronger antiseptic than carbolic acid, and withal has a pleasant odor.

Caoutchouc or *India-rubber* (Elastica U. S. P.), and *gutta-percha*. These are terpenes, which, insoluble in water, occur suspended in the milky juice of certain tropical plants. Caoutchouc is soft and elastic; gutta-percha is hard and brittle. Both can be vulcanized (combined with sulphur), the hardness, etc., depending on the amount of sulphur and heat used; so that many valuable articles are made from them. Caoutchouc dissolves in petroleum-ether and carbon disulphide; gutta-percha dissolves best in chloroform (liquor gutta-perchæ).

BENZENE SERIES. So named because they are all derived from

Benzene (Hexune) C_6H_6, and are also called "aromatic" because of their aromatic odor and taste.

Benzene[312] must not be confounded with *benzine,* one of the petroleum products. Benzene is distilled from coal-tar and is a colorless, volatile liquid of a peculiar odor, and a valuable solvent. It is especially interesting to the chemist for the great number and diversity of its derivatives. Treated with strong nitric acid, it yields *Nitrobenzene* or *oil of mirbane,*[313] a very poisonous substance used as a cheap perfume, especially in soaps.

Toluene (heptune), C_7H_8, is another member of this series, but of little medical interest, except sometimes used locally in diphtheria.

Naphthalene is the so-called "coal-tar camphor," and is employed in the form of moth-balls.

HALOGEN DERIVATIVES OF THE HYDROCARBONS. The hydrogen in the hydrocarbons is replaced by the halogens, viz., by chlorine, bromine, and iodine, forming halogen derivatives. They are for the most part colorless, ethereal smelling liquids, insoluble in water. If nascent hydrogen is allowed to act upon these derivatives, it combines with the halogen atom and returns the derivatives to their previous state, thus, $CHCl_3 + 3H_2 = CH_4 + 3HCl$.

Chloroform (trichlormethane) $CHCl_3$ is made[314] by distilling a strong solution of chlorinated lime and ordinary alcohol. Of late it is being manufactured more economically by a patented process from acetone, a bi-product in certain manufactures. Chloroform is a colorless, volatile liquid of a sweetish taste and an agreeable, ethereal odor. It is heavier than water and does not dissolve in it, but soluble in alcohol and ether. It is a solvent for phosphorus, iodine, india-rubber, the alkaloids, and

[312] *Benzene.* Heat a mixture of dry benzoic acid and quicklime and pass the vapor of the benzene evolved into a test-tube set in ice, Fig. 26.

[313] *Nitrobenzene.* Mix two parts of H_2SO_4 and one of HNO_3: let cool. Add benzene a drop at a time, shaking and cooling each time until 1 or 2 Cc. are added. Then pour into water and note the "essence of mirbane" sinking as a brownish-yellow oil to the bottom.

[314] *Chloroform.* In the apparatus shown in Fig. 26 distil 5 Gm. of chloral covered with KHO solution, and examine distillate for chloroform.

many other substances. Its vapor is heavier than air, but is not easily ignited. Yet it should not be administered it too near a flame, for fear of the poisonous, irritating fumes from its decomposition.

Chloroform is sometimes given by the stomach as a sedative but most frequently administered by inhalation as an anæsthetic, for which purpose it should be of undoubted purity.

Test of Purity :—Pure chloroform is not colored by an equal volume of pure sulphuric acid ; the specific gravity should not be below 1.480.

If chloroform be taken by the stomach, it being almost insoluble, is absorbed very slowly, and its principal action is the local irritation of the mucous surfaces. Recovery has followed a dose of four ounces, and death has been caused by one drachm taken into the stomach. The vapor acts more energetically and seems to owe its potency for evil to its paralyzing influence on the nerve centers, especially those of the heart. For this reason chloroform should never be administered except by a capable physician. It should be well diluted with atmospheric air. However, death has occurred from the inhalation of moderate quantities of chloroform properly diluted and at the hands of careful physicians, and where the autopsy revealed no heart lesion. There is no chemical antidote for chloroform. When it has been swallowed evacuate the stomach ; when inhaled, lower the head, give fresh air, employ artificial respiration, apply the induced current, and administer hypodermic injections of strychnine and whiskey. Chloroform should be kept in dark amber-colored bottles, and carefully corked to prevent evaporation.

In cases of intentional poisoning by chloroform the odor of the chemical is usually sufficient for recognition.

Bromoform—$CHBr_3$—is a colorless liquid of agreeable odor, formed by the action of bromine and potassium hydrate upon alcohol. It has been used as an anæsthetic, the advantage claimed being that both pulse and respiration remain about normal, even in prolonged narcosis. It is a valuable sedative in whooping

cough. It is, however, poisonous when taken internally in large amounts. In the case of two children, one four, the other four and one-half years old, recovery is reported after the ingestion of about 20 grains. In both cases ether and camphor were injected hypodermically to antagonize the bromoform.

Iodoform—CHI_3—is formed by the action of iodine and potassium hydrate on ordinary alcohol. It is a yellow, crystalline body, soluble in alcohol and ether, but insoluble in water. In spite of its disagreeable odor it is much used for its antiseptic effects— effects due not to the iodoform as such, but to traces of iodine liberated in its decomposition by the living tissues. The other therapeutic properties of iodoform are alterative, anæsthetic and anti-tubercular.

Alcohols and their Derivatives.

An alcohol is generally regarded as the hydrate of a hydrocarbon radical since its formula always has a hydrocarbon radical at its positive end, and the radical HO at the negative end. It might be regarded as formed by substituting the radical HO for an atom of hydrogen in the molecule of a saturated hydrocarbon : and again from H_2O in which one atom of hydrogen is replaced by a hydrocarbon radical.

METHYL SERIES.—The alcohols of most interest to the physician are those of the Methyl series of hydrocarbon radicals. They are often called the monatomic alcohols because all this series of radicals are univalent (monad.) The following table shows a few of them and their derivatives :

Radicals.	Alcohols (Hydrates).	Ethers (Oxides).	Examples of Compound Ethers.		Aldehydes.	Acids.
			Nitrates.	Sulphates.		
Methyl, CH_3	CH_3HO	$(CH_3)_2O$	CH_3NO_3	$(CH_3)_2SO_4$	CH_2O	CH_2O_3
Ethyl, C_2H_5	C_2H_5HO	$(C_2H_5)_2O$	$C_2H_5NO_3$	$(C_2H_5)_2SO_4$	C_2H_4O	$C_2H_4O_2$
Propyl, C_3H_7	C_3H_7HO	$(C_3H_7)_2O$	$C_3H_7NO_3$	$(C_3H_7)_2SO_4$	C_3H_6O	$C_3H_6O_2$
Butyl, C_4H_9	C_4H_9HO	$(C_4H_9)_2O$	$C_4H_9NO_3$	$(C_4H_9)_2SO_4$	C_4H_8O	$C_4H_8O_2$
Amyl. C_5H_{11}	$C_5H_{11}HO$	$(C_5H_{11})_2O$	$C_5H_{11}NO_3$	$(C_5H_{11})_2SO_4$	$C_5H_{10}O$	$C_5H_{10}O_2$
Hexyl, C_6H_{13}	$C_6H_{13}HO$	$(C_6H_{13})_2O$	$C_6H_{13}NO_3$	$(C_6H_{13})_2SO_4$	$C_6H_{12}O$	$C_6H_{12}O_2$
etc.	etc.	etc.	etc.	etc.	etc.	etc.

In the formation of these compounds the starting point is not the radicals, but their hydrates, the alcohols. When an alcohol is oxidized with a limited supply of oxygen, two atoms of hydrogen are removed and no oxygen is added. This forms the *aldehyde*, thus :

<div align="center">

Methyl   Methyl
Alcohol.   Aldehyde.

$$CH_3HO + O = CH_2O + H_2O.$$

</div>
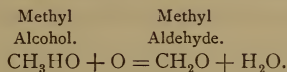
If there is a full oxidation, an atom of oxygen takes the place of the two atoms of hydrogen removed, and forms the corresponding acid, as—

<div align="center">

Methyl   Formic
Alcohol.   Acid.

$$CH_3HO + O_2 = CH_2O_2 + H_2O.$$

</div>
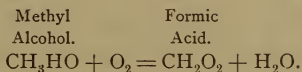
In the formation of aldehydes and acids the radical supplies part of the hydrogen removed and loses its identity. As part of the hydrogen in an acid forms the positive radical it is written first ; *e. g.*, formic acid is written $HCHO_2$, (rational formula) instead of CH_2O_2 (empirical formula). The various other compounds of these radicles are called *ethers ;* the oxides being called *simple ethers*, the others *compound ethers*. They are generally formed by treating the appropriate alcohol with the appropriate acid.

A *Ketone* is an organic compound consisting of the unsaturated radicle "CO" united to two univalent radicles, as in $(CH_3)_2 CO$, dimethylketone, commonly called *acetone*.

METHYL ALCOHOL—(CH_3HO), the so-called *wood spirit, wood naphtha, wood alcohol*, or *pyroligneous spirit*, is obtained from the destructive distillation of wood ; it does not exist in nature. When pure it resembles ordinary alcohol in its properties and physiological action, but the commercial article has a disagreeable odor and taste from the presence of tarry matters, etc. It is not used in medicine, but is employed widely in the arts as a substitute for ordinary alcohol, which, though cheaper to manufacture, cannot be sold as cheaply because of the tax imposed on alcoholic

beverages. In England ordinary alcohol is relieved of this tax and made available to the arts by mixing with it 10 per cent. of commercial methylic alcohol, which makes it unfit to drink.

ETHYL ALCOHOL, C_2H_5HO, also called *spirits of wine, vinic alcohol* and *alcohol*, is obtained in the spirituous fermentation of several varieties of sugar, such as grape-sugar, maltose, etc.

<div align="center">

Glucose.   Alcohol.   Carbon dioxide.

$$C_6H_{12}O_6 = 2C_2H_5HO + 2CO_2.$$

</div>
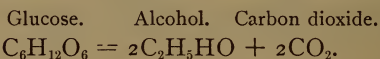
Liquids (wines, etc.), containing alcohol, have been known and used as beverages from the remotest antiquity.

From these the alcohol is separated by distillation, for being more volatile than the water it passes over first.[315] Commercial alcohol always contains water, and when pure, or "absolute" alcohol is required, the commercial article is mixed with some substance, which is very avid of water (as quick lime), and then again distilled. Ethyl alcohol may also be obtained experimentally from ethyl chloride (C_2H_5Cl), bromide (C_2H_5Br), or iodide (C_2H_5I), by replacing the halogen with HO. This is best accomplished by the agency of freshly precipitated silver oxide and water (practically silver hydrate) in the presence of heat, thus: $C_2H_5Br + AgHO = C_2H_5HO + AgBr$.

Alcohol is a light, colorless liquid of a pleasant, pungent odor and burning taste. It has great affinity for water, which fact probably accounts for its preserving animal tissues and coagulating the albuminoids. At minus 194° F. it is a thick liquid and at minus 266° F. a solid white mass. It boils at 173.6° F.

Test for Purity.—Absolute alcohol is soluble without turbidity in a small amount of benzene. If 3 per cent. or of more water is present in the alcohol cloudiness appears on adding the benzene.

Analyses for traces of alcohol in a solution are best made by oxidizing the alcohol into an aldehyde, or by converting the alco-

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[315] *Alcohol.* Distil some wine in apparatus shown in Fig. 26 [side neck test-tube distilling apparatus] and test distillate for alcohol by odor, taste and iodoform test.

hol, by means of dilute KHO (or NaHO) and iodine, into iodo-form.[316]

It is largely used in the arts and in pharmacy, principally as a solvent ; and also in the manufacture of various substances, as vinegar, chloral, chloroform, iodoform, ether, etc. ; as a fuel when a hot and smokeless flame is needed and as a menstruum in the preparation of tinctures and spirits. Alcoholic solutions of fixed medicinal substances are called " tinctures ;" those of vola-tile principles, " spirits." Alcohol is used in many forms and of various degrees of concentration. *Absolute alcohol* is rarely em-ployed, except in chemical analyses. *Alcohol, U. S. P.,* is the ordinary rectified spirit, and contains 91 per cent. of alcohol. *Alcohol dilutum, U. S. P.,* diluted alcohol, is made by mixing water and alcohol equal parts. *Spiritus frumenti, U. S. P.,* whisky, and *spiritus vini gallici, U. S. P.,* brandy, are obtained by distillation ; the former from fermented grain, and the latter from fermented grape juice. They contain about 50 per cent. of alcohol. Both are colored by the addition of caramel (burnt sugar). Their flavor is due to small quantities of other alcohols, produced in the fermentation, and to certain ethers formed from these alcohols, especially as the liquor " ages." A large class of alcoholic beverages are made by fermenting various liquids con-taining sugar or some substance capable of conversion into sugar.

Beer, ale and *porter* are infusions of malted grain fermented and flavored with hops. They, therefore, contain the soluble constituents of the grain. Their alcoholic strength is about 5 per cent. *Wines* are prepared by allowing grape juice to ferment. Various wines are used but the pharmacopœia recognizes only two classes, *White* and *Red*, each with an alcoholic strength of 10 to 14 per cent. *Cider* is the fermented juice of the apple and contains about 5 per cent. of alcohol. It is very prone to acetous fermentation and liable to produce colic and diarrhœa.

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[316] Warm the solution supposed to contain alcohol; add a few scales of iodine, and then caustic potash until the color is discharged. On cooling, yellow scales of iodoform are deposited.

Alcohol when concentrated abstracts water from the tissues and coagulates their albuminoid constituents ; and is a poison. In full doses (always best with food) alcoholic liquors produce a sense of warmth in the stomach, general comfort and exhilaration followed by incoherence of ideas and impairment of muscular co-ordination.

Taken habitually, in any of its forms, it impairs the mental and moral force of its victim, and produces in the various organs, especially the liver and kidneys, the degenerative changes characteristic of "chronic alcoholism." It should never be taken in health, but as a medicine it is the most valuable of stimulants. In cases of acute poisoning by alcohol, the stomach and bladder should be evacuated and the depression (coma) counteracted by strong coffee, the cold douche, and other stimulants.

Trityl (propyl) alcohol and *tetryl* (butyl) alcohol need only to be mentioned here ; in fact, the only other alcohol of this series possessing medical interest is pentyl alcohol.

AMYL ALCOHOL, *pentyl alcohol*, $C_5H_{11}HO$, *fusel oil*. This is a heavy liquid, soluble in alcohol but not in water, hence incorrectly called an oil. It is produced in fermentation of grain, potatoes and other starchy substances, and is the most deleterious impurity in common whisky, before it has undergone the refining process (rectification). It has a penetrating, disagreeable odor, resembling that of mean whisky. Although not fragrant itself, its ethers, when dissolved in ethyl alcohol, have the taste and odors of various fruits, and are used in the preparation of artificial essences.[317]

SULPHUR ALCOHOLS or *mercaptans*. It was noted in discussing the sulphur group (inorganic) that sulphur had the faculty, in a marked degree, of playing the same roles as oxygen and forming analogous compounds. The sulphur alcohols and ethers are strong smelling, irritating bodies, some of which are derived from ani-

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[317] To a half drachm of fusel oil in a test-tube add some sodium acetate, and a few drops of sulphuric acid. Warm the mixture, and the pentyl (amyl) acetate, "essence of pear" will be recognized by its odor.

mals and plants, *e. g.*, ichthyol and the oils of garlic and mustard. *Ethyl mercaptan* is ethyl sulphydrate, C_2H_5HS, a volatile liquid with a powerful odor of garlic—*Sulphonal*, a white, tasteless powder and valuable hypnotic is derived indirectly from it.

ETHERS.   An *ether* is an oxide of a hydrocarbon radical, for example, $(CH_3)_2O$; here it is noticed that O being bivalent, must unite with two molecules of the univalent methyl. These two molecules (methyl) being alike, $(CH_3)_2O$ (di-methyl oxide) is a *simple ether*. Where the two hydrocarbon radicals are unlike, it is a *mixed ether*, as (CH_3,C_2H_5) O (methyl ethyl oxide). Other compounds (except hydrates and oxides) of hydrocarbon radicles are called *compound ethers*, as CH_3NO_3, C_2H_5Cl, $(C_5H_{11})C_2H_3O_2$, and $CH_3C_2H_5SO_4$, in which hydrocarbon radicals are made to displace the hydrogen of nitric, hydrochloric, acetic and sulphuric acids respectively. The simple and mixed ethers (oxides) are generally made by dehydrating the appropriate alcohols with some substances very avid of water, as sulphuric acid, and distilling the resulting ether. The compound ethers generally, may be made by treating the appropriate alcohol with the appropriate acid, and distilling off the ether produced in the reaction.

ETHYL ETHER $(C_2H_5)_2O$, *Diethyl Oxide, Ether*, U. S. P.   It is formed by abstracting H_2O from alcohol, usually by means of sulphuric acid,[318] and hence often given the misnomer, " sulphuric ether."

The reaction is as follows : $C_2H_5HO + H_2SO_4 = C_2H_5HSO_4 + H_2O$: and then again, $C_2H_5HSO_4 + C_2H_5HO = (C_2H_5)_2O + H_2SO_4$.

To manufacture ether :—Take of ethyl alcohol (80 to 90 per cent.) five, parts ; of sulphuric acid, 9 parts ; mix, and warm in a flask with a condenser connection.   A thermometer passes through a cork and into the liquid.   When the temperature has reached 284° F., pour slowly more alcohol into the flask through

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[318] Into a large test-tube pour alcohol and half as much sulphuric acid; warm, and note the odor of ether evolved.   Next adapt a cork with delivery tube and slowly distil the ether into a cool test-tube.   By adding more alcohol the operation may be repeated again and again.

a second tube, opening through the cork. Keep the temperature at 284°. The ethyl-sulphate produced in the beginning reacts at 284° upon the alcohol as it enters, forming sulphuric acid and ether, which latter distils over with the water formed in the reaction. The distillate is a mixture of ether, water and alcohol. Shake with soda to get rid of the acid. The lighter layer of ether is siphoned off and distilled over lime. The alcohol is removed by distilling over sodium, un il hydrogen is no longer evolved. The sulphuric acid, being unaltered in the reaction, a small quantity is capable of converting a large amount of alcohol into ether ; in fact, the process might go on indefinitely but for the acid becoming so diluted with the water derived from the alcohol as to finally stop the reaction.

Ether is a colorless, very volatile liquid of a very peculiar odor, called ethereal ; and is highly inflammable. It burns easily, and its vapor mixed with air or oxygen explodes when ignited.[319] So ether should never be used near, especially above, a flame. Ether is a valuable solvent, and as it evaporates very rapidly, it is used to produce cold.[320] But its chief use in medicine is as an anæsthetic, the vapor being inhaled. Being less liable to paralyze the nerve centers, it is safer than chloroform. As a solvent of carbon compounds, such as fats, resins, etc., it has a very extended use. Commercial ether contains 94 per cent. of ether and is only employed as a solvent.

Test for purity of ether :—Water in ether is detected by a turbidity when the ether is shaken with an equal volume of CS_2. Alcohol is detected by shaking with aniline violet which, if alcohol is present, causes a coloring of the ether.

ETHYL CHLORIDE C_2H_5Cl, *hydrochloric ether,* must not be confounded with the so-called "chloric ether," which is an alcoholic solution of chloroform.

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[319] Put a drachm of ether in a dish and apply a flame. The vapor, having mixed with air, explodes; the rest of the ether burns rapidly.

[320] Set a test-tube of water in a beaker of ether. Blow air briskly through the ether; the water will freeze.

ETHYL BROMIDE C_2H_5Br, *hydrobromic ether*, a valuable anaesthetic, but not much used. It is of great importance to have a pure article for internal use, since with an impure one alarming after-effects have occurred. Externally, ethyl bromide is useful as a spray in neuralgia.

ETHYL NITRITE $C_2H_5NO_2$, *nitrous ether:*—If nitric acid is treated with copper or starch it loses part of its oxygen, and is converted into nitrous acid (HNO_2). If alcohol also is added it is attacked by the nascent nitrous acid and converted into nitrous ether and water,[321] thus: $C_2H_5HO + HNO_2 = C_2H_5NO_2 + H_2O$.

Nitrous ether is a yellowish liquid of an apple-like odor and sweetish taste. It is inflammable and is exceedingly volatile. It is used diluted with alcohol, forming the *spiritus etheris nitrosi*, U. S. P., commonly called "sweet spirits of nitre."

PENTYL NITRITE : $C_5H_{11}NO_2$.—Called commonly *amyl nitrite*. Made like ethyl nitrite except that pentyl alcohol (fusel oil) is used.[322] Nitrite of amyl is a volatile, oily liquid of peculiar odor, resembling that of bananas; and is unstable. It is given by inhalation, especially in angina pectoris, asthma, syncope, tetanus, epilepsy, etc. It is the antidote to cocaine. Put up in glass tubes and given in doses of two to four drops in brandy, or one to three drops by inhalation on the handkerchief. Amyl nitrite is so volatile that it is almost impossible to keep it in stoppered bottles without loss, especially in warm weather or where it is often agitated.

ALDEHYDES. These constitute the first step in the oxidation of alcohols to acids, viz.: the removal of hydrogen; hence the name. Since nothing has taken the place of the hydrogen removed, they are unsaturated and very prone to change, especially to take on oxygen and form acids. The lower aldehydes are volatile liquids, having a peculiar odor; the higher are solids.

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[321] *Nitrous Ether*. Distil a mixture of 1 Cc. of H_2SO_4 and 2 Cc. of HNO_3 and 10 Cc. of alcohol, and note odor of ethyl nitrite in the distillate.

[322] *Amyl Acetate*. Distil a mixture of 2 Gm. of sodium acetate, 5 Cc. of amyl alcohol and 2 Cc. of H_2SO_4, and note pear-like odor of amyl acetate.

METHYL ALDEHYDE (CH_2O), commonly called *formaldehyde*, is made by the oxidation of methyl alcohol. It is of great practical as well as theoretical interest, for besides being a valuable reducing agent, it is a most powerful antiseptic and preservative, especially of the albuminoids, which it attacks, even in vapor, with great avidity, making them insoluble, imputrescible and even indigestible. A 40 per cent. solution of it is sold under the name of "formaline," for preserving and hardening anatomical specimens.

ETHYL ALDEHYDE, C_2H_4O, *acetic aldehyde*, or simply *aldehyde*, made by the partial oxidation of ethyl alcohol,[323] is a colorless, volatile, acid liquid of a pungent, disagreeable odor and taste. It is hungry for oxygen and therefore a powerful deoxidizer.[324]

Paraldehyde is a modified or polymeric form of aldehyde, its formula being $C_6H_{12}O_3$ instead of C_2H_4O. It is produced by the action of small quantities of an acid on ethyl aldehyde, slight heat being employed. Paraldehyde is a colorless liquid, and a hypnotic, anti-spasmodic stimulant; and exhibits some diuretic properties. It has none of the depressing effects of chloral, nor the unpleasant after-effects of morphine, the chief objection to its use being its odor and taste.

CHLORAL.—If chlorine displaces three atoms of hydrogen in ethyl aldehyde, it forms *tri-chlor-aldehyde*, or chloral (C_2HCl_3O), a colorless, heavy liquid. With a molecule of water, this forms a white crystalline solid, called *chloral hydrate*, having a pungent but an agreeable odor and taste. Warmed with an alkali, it decomposes thus:

$$\underset{\text{Chloral.}}{C_2HCl_3O} + NaHO = \underset{\text{Sod. Formate}}{NaCHO_2} + \underset{\text{Chloroform.}}{CHCl_3}.$$
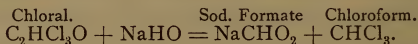
Liebreich thought this reaction would occur in the warm alka-

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[323] To a little "bichromate and sulphuric acid mixture" in a test-tube, add a little alcohol; or hold a hot glass rod in a beaker containing a little ether. The peculiar, pungent odor is that of aldehyde.

[324] To 2 Cc. of aldehyde in a test-tube add a weak solution of ammonio-nitrate of silver; the silver salt is deoxidized (reduced) and the metallic silver deposits on the sides of the vessel, forming a mirror.

line blood and the sedative action of chloroform be obtained. He mistook as to this, but found chloral hydrate a valuable hypnotic ; dose, grains 5 to 20. The chloral habit is difficult to cure. In overdoses, chloral is a poison, and cases are multiplying as its powers become better known. No chemical antidote. Evacuate the stomach, give stimulants, and maintain the respiration and bodily warmth. Chloral hydrate prevents decomposition and is therefore a good preservative of animal tissue.

CROTON CHLORAL, *chloral butylicum*, is a crystalline body, resembling chloral. Its action is much feebler than that of chloral. The dose is about the same.

ACETONE or *di-methyl ketone*, C_3H_6O. Acetone is a typical member of a class known as *ketones*, produced in various reactions, but especially in destructive distillation. Acetone is a colorless, inflammable liquid of a fragrant, mint-like odor and a sharp, biting taste. It is given in doses of from 5 to 15 drops, in water, as an alterative and anthelmintic. In acute alcoholism and in certain fevers, but more especially in the latter stages of diabetes mellitus, acetone appears in the blood (acetonæmia), and is attended with lowered temperature, and pulse-rate and general depression, until the patient finally dies in coma.

ORGANIC ACIDS.—These are, in general, the products of the complete oxidation of certain alcohols. But many of them, being discovered long before this relation to the alcohols was known, were given names that refer, not to the alcohols from which they are derived, but to some source, quality, use or fancied resemblance. For example, the oxidation-product of ethylic alcohol being first found in vinegar (acetum), was, and is still, called acetic acid, though ethylic acid would be a more appropriate name.

FORMIC ACID occurs in the red ant (*formica rufa*—hence its name), in stinging-nettle and pine-needles. It is the oxidation product of methyl alcohol, but it is best made by distilling a mixture of concentrated glycerine and dry oxalic acid. It is a colorless liquid with a very sour taste.

ACETIC ACID.—$HC_2H_3O_2$.—This is the acid of vinegar. Formed

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in a great many reactions, but made mainly by the destructive distillation of wood, or by the oxidation of ordinary alcohol. If wine, cider, or other alcoholic liquor is exposed to the air, a fungus (*mycoderma aceti*) called " mother of vinegar " forms on the surface and acts as an oxygen carrier, and the alcohol is converted into acetic acid, thus :

$$C_2H_5HO + O_2 = HC_2H_3O_2 + H_2O.$$
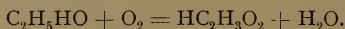
A more rapid process is to pass the alcohol through barrels filled with beech shavings covered with " mother of vinegar."

Acetic acid is a colorless liquid, of a pungent, sour taste and smell. When free from water (glacial) it crystallizes at temperatures below 60° F. Acetic acid in dilute solution (vinegar) is much used for domestic purposes. For medicinal use the crude vinegar is purified by distillation, forming *acidum aceticum dilutum*, U. S. P.

As all the acetates are soluble, their best test is to add a strong acid and recognize by its odor, the acetic acid set free.[325]

BUTYRIC (*tetrylic*) ACID occurs in rancid butter, human perspiration, fæces, etc., and pathologically in urine, sputum, etc. It is formed by the oxidation of tetryl alcohol, but is best made by fermentation of a mixture of sugar, cheese and chalk ; calcium butyrate being formed, from which the acid can easily be obtained on adding sulphuric acid and distilling. It is a colorless liquid with the odor of rancid butter.

VALERIANIC (*pentylic*) ACID was first obtained (and named) from valerian root, but is now made artificially by oxidizing amyl (pentyl) alcohol with sulphuric acid and potassium bichromate.[326] It is a thin oily liquid, of a sour taste and disagreeable and persistent odor of rotten cheese or rats' nests.

FAT ACIDS.—Of this series of organic acids, the higher members,

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[325] *Test for acetic acid.* To a strong solution of an acetate add H_2SO_4 and a little alcohol. Warm and note fragrant odor of ethyl acetate.

[326] *Valerianic acid.* Distil (Fig. 26 [side neck test-tube, etc.]) a mixture of 10 Gm. of $K_2Cr_2O_7$, 1 Cc. of H_2SO_4 and 4 Cc. of amyl alcohol. Redistil the distillate and note odor, etc., of valerianic acid.

such as *Palmitic*, *Stearic*, together with *Oleic* (which belongs to another series), exist in most of the *natural fats* which are compound ethers of various hydrocarbon radicles, especially *Glyceryl* (C_3H_5), with the above-mentioned and other fat-acids.[327] The natural fats are generally a mixture of several fats. Those containing mostly oleate of glyceryl (olein) are liquid ; those containing the palmitate or stearate are solid at ordinary temperatures. So the cold-blooded animals have liquid fats (largely olein) ; while warm-blooded, yield mostly the solid fats. Many fats partially decompose and oxidize on exposure, producing free acids and becoming *rancid*. Especially is this true of butter which, in addition to palmitine, stearine and other fats, contains also a certain quantity of cheese-curds, etc. " Oleo-margarine," or artificial butter, is made from purified fat (mainly palmitine and oleine) by churning it in milk and adding some coloring. Drying oils are such as absorb oxygen from the air and become resinous, *e. g.*, linseed oil. The fats are fixed (not easily volatilized), insoluble in water, soluble in alcohol, ether, etc.

If a metallic radicle is made to replace the positive (hydrogen) radicle of the fat-acid, we obtain, especially with the higher members of the series, a class of substances called "*soaps*." The soaps then are compounds of the metallic radicles with fat-acids. The soaps of the alkali-metals (K, Na, NH_4, etc.) are soluble and constitute the true and useful soaps. The soaps formed with the other metallic radicals are insoluble, and are usually called *plasters ;* lead plaster[332] is officinal. The " curding " of soluble soaps in hard water or water containing salts of metals other than

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[327] To 5 Cc. of soap solution add HCl, and note the separation of oily globules of fat acids.

Plasters. Add to successive portions of a soap solution and water :

[328] $MgSO_4$ and note white precipitate of magnesium soap.

[329] $FeSO_4$ and note greenish precipitate of ferrous soap.

[330] $FeCl_3$ and note brown precipitate of ferric soap.

[331] $CuSO_4$ and note blue precipitate of copper soap.

[332] $Pb(C_2H_3O_2)_2$ and note white precipitate of lead soap.

HOMOLOGOUS SERIES OF FAT-ACIDS.*

Common Name.	Empirical Formula.	Melting Point. F.	Boiling Point. F.	Properties.	Natural Source.
Formic,	CH_2O_2	47	212	Colorless volatile liquid.	In red ants and some other insects and in some stinging plants.
Acetic,	$C_2H_4O_2$	62	246	Colorless pungent liquid.	Oxidation of alcohol and sugar.
Propionic,	$C_3H_6O_2$	62	286	Crystalline solid.	
Butyric,	$C_4H_8O_2$	−10	325	Colorless liquid of disagreeable odor.	Butter and other animal secretions.
Valeric,	$C_5H_{10}O_2$	{28}{13}	365	Colorless liquid of disagreeable odor.	Valerian root.
Caproic,	$C_6H_{12}O_2$	.....	401	Colorless oily body.	Butter and coconut oil.
Enanthylic,	$C_7H_{14}O_2$	.....	434	Slightly soluble in water; has an agreeable odor.	Oxidation of castor oil.
Caprylic,	$C_8H_{16}O_2$	61	456	....	Butter, coconut and castor oils.
Pelargonic,	$C_9H_{18}O_2$	54	488	Crystalline solid.	Geranium leaves.
Capric,	$C_{10}H_{20}O_2$	86	516	Crystalline mass having the odor of sweat.	Butter and coconut oil.
Lauric,	$C_{12}H_{24}O_2$	110	.....	Silky crystals.	In coconut oil.
Myristic,	$C_{14}H_{28}O_2$	129	.....	Crystalline scales.	In nutmeg and coconut oil.
Palmitic,	$C_{16}H_{32}O_2$	143	.....	Fat-like solid.	Most natural fats.
Margaric,	$C_{17}H_{34}O_2$	140	.....	"	Resembles palmitic.
Stearic,	$C_{18}H_{36}O_2$	158	.....	"	Most natural fats.
Arachidic,	$C_{20}H_{40}O_2$	167	.....	White, crystalline, fatty solid.	Peanut oil.
Byeenic,	$C_{22}H_{44}O_2$	169	.....	" "	Oil of ben.
Hronic,	$C_{25}H_{50}O_2$	171	.....	Resembles Cerotic.	
Cerotic,	$C_{27}H_{54}O_2$	178	.....	Crystallizes in small grains.	Free in beeswax.
Melissic,	$C_{30}H_{60}O_2$	191	.....	....	Derived from beeswax.

Leffman.

the alkali-metals is due to the precipitation of insoluble soaps or plasters. Soaps are made by the *saponification* of a fat with a caustic alkali. For example :—

$$\underset{\text{Stearine.}}{(C_3H_5)(C_{18}H_{35}O_2)_3} + 3NaHO = \underset{\text{Sodium Stearate.}}{3NaC_{18}H_{35}O_2} + \underset{\text{Glycerine.}}{C_3H_5(HO)_3}.$$
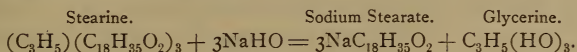
When soap dissolves in cold water, it probably decomposes into an acid salt which makes the soapsuds [331] and a small quantity of free alkali which does the cleaning by dissolving and, to some extent, by emulsifying by the fats.

Methene Series. This series of radicles is bivalent, so that their alcohols or acids are *diatomic* or *dibasic*. Their alcohols are unimportant except, perhaps, *ethene alcohol* or *glycol* $C_2H_4(HO)_2$, which though of some chemical interest, has no practical application in medicine. Most of the acids of this series are *Diatomic or Dibasic*.

OXALIC ACID, $H_2C_2O_4$, occurs in many plants, mainly as potassium binoxalate, especially in the sorrel (oxalis) grasses, and in the animal economy appearing in the urine, occasionally forming calculi of calcium oxalate. It is largely and cheaply made from sugar or saw-dust by the oxidizing action of nitric acid or caustic alkalies. It is a crystalline solid and closely resembles Epsom salts, for which it is sometimes taken by mistake. It is a powerful irritant poison ; and being cheap and largely used for removing ink-stains, cleaning copper, etc., poisoning by oxalic acid is by no means rare. Its best antidote is chalk or some other compound of calcium, with which it forms a very insoluble compound. Its best test is some calcium solution, as chloride, forming a white precipitate insoluble in acetic but soluble in hydrochloric acid.

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[333] $HgCl_2$ and note white precipitate of mercuric soap.

[334] *Lather.* Pour 1 Cc. of soap solution into some soft water in a test-tube; shake and note lather.

[335] *Lime soap.* Next add $CaCl_2$ and shake; note no lather, but a curd of lime soap.

[336] *Softening hard water.* To a portion of soap solution add Na_2CO_3, and then $CaCl_2$. Shake and note that $CaCO_3$ is precipitated and a lather forms.

LACTIC ACID, $H_2C_3H_4O_3$ (*lactis*, of milk).—This is the acid of
sour milk, where it is formed by the fermentation of the sugar of
milk through the agency of the casein. It is also formed in the
body by the decomposition of glucose, thus :—

$$C_6H_{12}O_6 = 2H_2C_3H_4O_3.$$
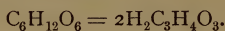
It is a syrupy liquid, of a very sour taste.

SUCCINIC ACID, $H_2C_4H_6O_4$, is found in amber (*succinum*),
lignite, resins, and in certain animal fluids. When fats are oxidized
with nitric acid, succinic acid is formed. It is now usually made
by fermenting malic acid.

Colorless, odorless prisms, soluble and with an acrid taste ; used
as an anti-spasmodic and diuretic.

MALIC ACID, $H_2C_4H_4O_5$ (*malum*, an apple`), exists in many sour
fruits and plants, as apples, cherries and garden rhubarb, but may
be made artificially from succinic acid. The acid and its salts
are mostly soluble.

TARTARIC ACID, $H_2C_4H_4O_6$, or H_2T.—Tartrates exist in the juices
of many fruits. Grape juice contains much acid tartrate of potas-
sium (KHT), which, being very insoluble in an alcoholic men-
struum, is precipitated on the sides of the cask whenever the wine
ferments. This forms *argol*, the principal source of cream of tar-
tar and tartaric acid. Tartaric acid forms colorless crystals, very
soluble, and of a sharp, agreeable, sour taste.

It is used in the manufacture of baking powders, in Seidlitz
powder, and in effervescent drinks.

CITRIC ACID is closely related to tartaric acid in its sources pro-
perties and uses, but it is triatomic or tribasic. It exists in the
juices of many fruits, especially the lemon. Forms colorless crys-
tals which are very soluble, and possess a sour taste. Many of
its salts are used in medicine.

Methenyl Series.—These are trivalent radicles, and form tria-
tomic alcohols and acids. The most important member of the
series is *tritenyl*, C_3H_5, sometimes called *propenyl*, and more
commonly *glyceryl*. Its alcohol is

GLYCERINE, or *glycerol*, $C_3H_5(HO)_3$. Being made from fats, in the manufacture of soaps and candles, it has been called (Scheele, 1779) "the sweet principle of fats;" but it has no chemical analogy with those ethers, since it is the hydrate of tritenyl, and therefore an alcohol. Glycerine is produced in the saponification of fats, whereby the fats are broken up into fat acids and glycerol, thus :

Tritenyl Stearate.   Sodium Stearate. Glycerol.
$$(C_3H_5)(C_{18}H_{32}O_2)_3 + 3NaHO = 3NaC_{18}H_{35}O_2 + C_3H_5(HO)_3.$$
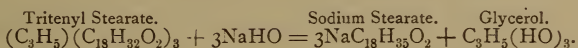
It is a colorless, odorless, sweet, viscid liquid, avid of water, neutral in reaction, soluble in all proportions in water and in alcohol, and a solvent of a great many mineral and organic substances, the solutions being called *glycerites*. On account of its hygroscopic property, it has a wide scope of usefulness in therapeutics as a laxative, as a depletant and emollient.

Tritenyl Nitrate, $C_3H_5(NO_3)_3$, usually called nitroglycerine. When glycerine is added drop by drop to a mixture of equal volumes of strong nitric and sulphuric acid, until the glycerine no longer dissolves, and the liquid is then poured into water, nitroglycerine separates as a colorless, heavy, oily-looking substance of a peculiar odor and sweet taste. It is a powerful explosive, and to prevent its accidental explosion on percussion, it is usually mixed with some inert dry powder, as silica, sawdust or powdered charcoal, and sold as *dynamite* or giant powder. Nitroglycerine is much used in medicine (dose, $\frac{1}{100}$ gr.) as a powerful and quick heart stimulant.

PHENOL, *phenyl alcohol* (hydroxybenzene), C_6H_5HO, is generally called *Carbolic Acid*, also phenic, or phenylic, acid ; called an acid because it combines with bases to form salts, the carbolates, or phenates. It belongs in the class of benzene, or aromatic alcohols.

Carbolic acid is formed in a number of reactions, but the commercial article is obtained exclusively from coal tar. It has a strong, disagreeable odor; stains skin and mucous membranes white by coagulating their albumin; and is a corrosive poison.

Care should be exercised in its local application over large surfaces, even in dilute solution, especially on infants, as poisoning may occur by absorption. Injections of carbolic acid are used to abort boils and carbuncles and also in the treatment of hemorrhoids ; and many fatalities are recorded. Antidote : any soluble sulphate as $MgSO_4$, then albumin (milk, egg, etc.) in abundance ; but the most efficient antidote has recently been found to be alcohol. For burns by carbolic acid, glycerine is an excellent remedy.

Sulphocarbolates. Carbolic acid will unite with sulphuric acid and form *sulphocarbolic acid,* $C_6H_5HSO_4$ (phenyl-bisulphate) from which are formed the sulphocarbolates, a class of astringent, antiseptic salts, much used in medicine.

Resorcin, $C_6H_4(HO)_2$, closely related to phenol, but a stronger antiseptic and much less poisonous. It is obtained from various resins or prepared from benzene.

Creasote is a complex mixture obtained from wood-tar ; closely allied to carbolic acid in its properties and uses, but may be readily distinguished from it by being insoluble in glycerine. The best creosote is obtained from beech-wood. It is a colorless, or faintly yellow, oily liquid, of a characteristic odor and caustic, burning taste. It is at present a popular remedy in pulmonary tuberculosis, and has long been used as a sedative and astringent in vomiting and diarrhœa, and as a local anæsthetic. Large doses are poisonous and the antidote is the same as for carbolic acid.

Guaiacol is a constituent of creasote and is prepared from it by fractional distillation. It is a colorless, limpid, oily liquid of a characteristic, aromatic odor and taste ; extensively used in tuberculosis, both pulmonary and intestinal. *Guaiacol carbonate* is better adapted for internal medication, since it is neutral, odorless and tasteless, and therefore less irritating. Dose, 2 to 5 grains gradually increased to a drachm or more a day. Both guaiacol and its carbonate must be given for quite a time in tuberculosis before their full effects are obtained.

Cresol occurs in several modifications in coal-tar, creosote, phenol, etc., and is also made artificially. Though more powerfully antiseptic than phenol, it is much less caustic and poisonous. Under the trade names of " creolin," "lysol," etc., it is sold for domestic use as an antiseptic.

Salol is phenyl salicylate, $C_6H_5C_7H_5O_3$, and is an ether. It is a white powder, tasteless and insoluble in neutral and acid media, but in the presence of the fixed alkalies it breaks up into phenol and a salicylate.[337] When taken, it passes through the stomach unchanged, to be decomposed and made available in the bile and intestines ; hence used as an intestinal antiseptic and antirheumatic.

Salophen resembles salol in its physical, chemical and physiological properties and therapeutic uses.

Saccharin is a white powder, slightly soluble in water, but at least 200 times as sweet as sugar, from which its name is derived. It has no chemical analogy to the sugars, but is closely related to the phenols. It is used as a substitute for sugar in sweetening, but has the disadvantage of disturbing digestion.

BENZOIC ACID.—$HC_7H_5O_2$, occurs in benzoin, from which it may be sublimed in silky needles slightly soluble in water and of a pleasant, balsamic odor.[338] Much is now made from hippuric acid, obtained from the urine of herbivorous animals ; but such benzoic acid has a urinous odor. It is made industrially by the oxidation of benzene. Is given in doses of 15 grains, as an expectorant and as an antiseptic in cystitis, its presence in the urine destroying the germs of the alkaline fermentation. This and the following acids belong the class of " Aromatic Acids."

PICRIC OR CARBAZOTIC ACID is *trinitro-phenol*, $C_6H_2(NO_2)_3HO$, *i. e.*, phenol in which three molecules of (NO_2) have replaced

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[337] *Salol Test*, U. S. P. Warm 1 Gm. of salol with liq. potassæ enough to dissolve it ; supersaturate with HCl, and note the precipitation of silky needles of salicylic acid, and the odor of phenol.

[338] *Benzoic acid*. Warm a small lump of benzoin in a test-tube, and note sublimate (needles) of benzoic acid.

three atoms of hydrogen ; and is made by treating phenol with nitric acid.[339]   It crystallizes in a yellow powder slightly soluble in water and is much used as a dye.   If warmed carefully it may be sublimed, but if heated suddenly, explodes with violence.   It behaves as a monobasic acid, and its salts are mostly solid yellow, crystalline bodies, some of which are used in medicine.   Vast quantities are now used in the manufacture of explosives, as "lyddite."   It may be recognized by its bitter taste and yellow color ; by its coagulating albumin and peptone ; and by a blood-red with glucose and a dilute alkali.

SALICYLIC ACID (monobasic).—Formerly prepared from salicin, but now made by a patented process from carbolic acid.   A very pure acid is obtained from oil of wintergreen, which consists mainly of methyl-salicylate.[340]

Salicylic acid is almost insoluble in cold water ; hence the sodium salicylate is usually prescribed, which is also less irritating, though not so bland as the corresponding strontium salt.   It has antiseptic, antipyretic and antirheumatic properties and a wide range of usefulness as an application in skin diseases.   Test : intense violet with a ferric salt.

GALLIC ACID.—When galls are moistened and exposed to the action of the atmosphere, the tannin they contain is converted into gallic acid.   It resembles tannin but does not precipitate gelatin.   So the gradual conversion of tannin into gallic acid incidental to leather manufacture is a source of constant loss to the tanners, since gallic acid does not tan.

PYROGALLIC ACID sublimes as white, feathery crystals when gallic acid is heated.   Combined with an alkali, it is used in gas-analysis

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[339] *Picric acid.*   Mix 5 Cc. of dilute nitric acid and 2 Cc. of carbolic acid and let it cool; boil with 10 Cc. of strong HNO_3 for several minutes, adding more HNO_3, drop by drop, as long as carbolic acid floats on top.   Finally cast into 25 Cc. of cold water.   Note the yellow crystals of picric acid, and that when they are dried and dropped into a fire they explode.

[340] To 1 Cc. of oil of wintergreen in a test-tube add 5 Cc. of liq. potassæ; heat until saponification and solution is complete; add HCl and note the mass of silky, white crystals of salicylic acid.

to absorb oxygen ; in photography as a deoxidizer ; externally in psoriasis and other skin diseases ; and also as hair-dye. Test : a blue with ferrous and a red with ferric solutions.

The Carbohydrates.

These substances are closely related to the alcohols, being probably aldehydes. They are called "carbohydrates" because they contain carbon (six or twelve atoms) and the hydrogen and oxygen they contain are in the exact proportion to form water. They constitute the bulk of all plants. They are divided into three groups : Amyloses, $C_6H_{10}O_5$; saccharoses, $C_{12}H_{22}O_{11}$, and glucoses, $C_6H_{12}O_6$.

AMYLOSES, $C_6H_{10}O_5$. This class includes cellulose, gums, starch, dextrin and glycogen.

CELLULOSE (cellulin, lignin) forms the cell-walls and tissues of plants, and is a distinctive characteristic of the vegetable kingdom. Woody fibre, cotton, linen and unsized paper are almost pure cellulose. It is insoluble in almost every[341] reagent except a solution of cupric oxide in ammonia-water.[345] Acids precipitate it as a white mass.[346] Unsized paper dipped into moderately strong sulphuric acid, washed and dried, has its fibres agglutinated, loses its porosity, becomes very tough, and is sold as artificial parchment for dialyzers, diplomas, etc. *Nitrocellulose* or "gun-cotton," a powerful explosive, is cotton that has been dipped into a mixture of nitric and sulphuric acids, and then

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[341] *Cellulose.* Put bits of filter paper in three test-tubes.

[342] To one add water and boil; no effect.

[343] To the second add KHO solution; the fibres swell and become gelatinous.

[344] To the third add H_2SO_4, and note that it turns black.

[345] To the fourth add cupric hydrate solution (made by dissolving $Cu(HO)_2$ in aqua ammoniæ), and note that the paper is dissolved.

[346] To the solution add HCl until the ammonia is neutralized and the deep blue color discharged, and note that the cellulose is precipitated as a gelatinous mass.

[347] *Artificial parchment.* Immerse a sheet of filter paper in strong H_2SO_4 for about 15 seconds; wash thoroughly and dry. Note that the fibres have become agglutinated and the paper made stronger.

washed and dried. Mixed with camphor and compressed it is *celluloid.* Its solution in ether, or in a mixture of alcohol and ether, is *collodion.*[348] The "flexible collodion" contains a little turpentine and castor oil; the "styptic collodion" contains 20 per cent. of tannin.

GUMS are amorphous, odorless, tasteless, sticky substances; found in many plants; soluble in water but insoluble in alcohol. Some, as gum-arabic, make clear solutions (mucilages) with water, while others, like gum-tragacanth, only swell up and form a paste.

STARCH (*amylum*), the most important member of the carbo-hydrates, and a valuable food, is found in the roots,[351] stems or seeds[349] of all plants. Starch is a white powder consisting of granules formed of concentric layers, like an onion.[351] These granules all have a similar appearance, yet those from different kinds of plants differ enough to enable one by microscopic examination to determine the source of any starch (Fig. 39). When starch is boiled the granules swell and burst, casting starch into the water, appearing to dissolve[353] and forming mucilage of

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[348] *Collodion.* Immerse a pledget of absorbent cotton 15 minutes in a mixture of 2 parts of strong H_2SO_4 and 4 of HNO_3; wash thoroughly and dry. Note that it burns with a flash, and is soluble in a mixture of ether and alcohol.

[349] *Starch.* Grind some rice in a mortar, adding water from time to time, and strain the milky fluid through a cloth. Separate the starch by subsidence and decantation, and finally dry it on filter paper.

[350] *Granules.* Mount a drop of the milky fluid above mentioned under a cover glass on a slide for examination later, when the peculiar structure of the granules can be noted.

[351] *Starchy tissue.* Mount a microtome section of potato, and note, under a power of about 300 diameters, the granules arranged in cells, and that on addition of reagents, such as iodine, the granules are blued and the cell walls (cellulose) unaffected. Note also the difference between potato and corn starch granules.

[352] *Starch Paste.* (1) To 1 Gm. dry starch add KHO solution, and note that, even in the cold, the granules swell and the milky mixture becomes translucent; and

[353] (2) Boil another 1 Gm. of starch with plain water, and note same change.

starch,[354] which is used for laundrying and for surgical dressings. Starch is a very valuable food. Its best test is iodine,[35;] with which it forms a blue, which is somewhat lost on heating and regained on cooling.[355]

DEXTRINE is the gum used on postage stamps, and by bookbinders, and is made from starch in various ways, one of which

FIG. 39.

a   c   d

Arrowroot.   Indian Corn.   Potato.
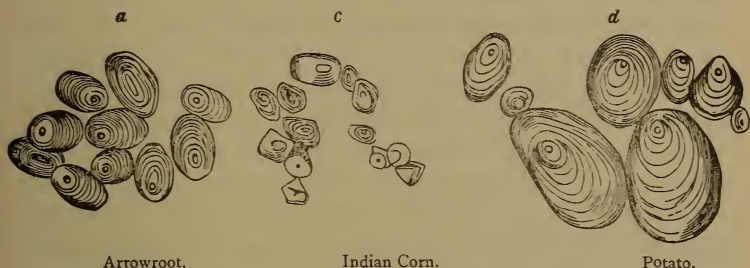
is to heat it to 300 F. for some hours. It is more soluble than starch,[360] and this explains the digestibility of crusts and toasted bread. It gives no blue with iodine, but a reddish, or wine color.[361]

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[354] Dissolve a few drops of starch paste in water, and add a drop of iodine solution. Note blue color.

Divide this blue solution between four test-tubes.

[355] Heat one and note that the blue color disappears, but re-appears on cooling, unless heated so strongly that the iodine is drawn off.

[356] To the second add KHO solution, and note the blue is discharged, but is restored on adding HCl.

[357] To the third add $AgNO_3$ solution, and note that the blue disappears.

[358] To the fourth add $HgCl_2$ solution, and note again that the blue disappears.

[359] Filter some diluted starch paste, and note that it still responds to the tests for starch.

[360] Dextrin. Take about 1 Gm. of commercial dextrin purchased by the demonstrator at the book-binder's. Add it to water, and note that it is soluble, sticky and sweet.

[361] Add a drop of this solution to alcohol, and note that it falls as a white precipitate, dissolving again on addition of water. To some dextrin solution add iodine and note reddish (claret) color.

GLYCOGEN (generator of glucose) is a mealy, soluble powder found in the animal economy, especially in the liver. Like dextrin it is a derivative of starch, but differs from it in being soluble and giving only a wine-color with iodine. It seems to be the form in which the carbohydrates are stored up in the liver to be used by the system as necessity arises.

SACCHAROSES, $C_{12}H_{22}O_{11}$. This group includes cane-sugar, milk-sugar and maltose.

CANE-SUGAR, beet-sugar, sucrose (*saccharum* U. S. P.) is found chiefly in sugar cane and also in beet roots as well as in sugar maple. Cane-sugar occurs in the juice of many plants, especially in the stalks ; but in the fruit, unless very sweet, the glucoses occur oftener. It is made commercially as follows : The sap of sugar cane or the juice of beet-root is expressed by pressure or extracted with warm water and boiled with milk of lime, which saturates the acids and precipitates the albuminoid substances. The juice is then saturated with carbon dioxide to precipitate the lime, filtered through animal charcoal and concentrated in the " Robert's machine." By further evaporation in vacuum pans a thick syrup is obtained, and on cooling the solid sugar separates. This is *raw* or unrefined sugar, which when purified with a " pure sugar solution " in a centrifugal machine becomes *refined* sugar. It is the most soluble, perfectly crystallizable and sweetest of the sugars, and the one most used in domestic economy. Its aqueous solution is officinal as simple syrup (syrupus simplex). It does not respond to the tests for glucose.[362]

MILK-SUGAR, as its name implies, occurs in milk, though occasionally elsewhere, as in the liquor amnii of the cow and in certain pathological secretions. Prepared by evaporating whey until the sugar crystallizes out, and is purified by repeated crystallization. It is harder, less soluble and less sweet than cane-sugar and used

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[362] *Cane Sugar.* (a) Apply Fehling's test to a solution of cane-sugar, and note that there is no reduction.

[363] (b) Boil with 5 per cent. H_2SO_4 or HCl, and, after neutralizing the acid with an alkali test for the presence of glucose.

in the trituration of medicines.[366] As it is less prone to fermentation than other sugars, it is preferred in infant feeding. On fermentation, it forms lactic acid and not alcohol and acetic acid as do other sugars.

MALTOSE is a sugar formed by the action of malt diastase upon starch, as in the "mash" of whiskey and beer; also produced by the action of animal ferments on glycogen. In its power to reduce Fehling's solution, 61 parts of maltose equal 100 of glucose.

GLUCOSES, $C_6H_{12}O_6$. Of this group we need mention only glucose and laevulose.

GLUCOSE, or grape-sugar, occurs in most sweet fruits, especially in the grape, and in honey. It is the sugar of the animal economy and the one that appears in the urine in diabetes mellitus. It is formed in nature largely by the action of acids and ferments [317-371] in conjunction with warmth and moisture on the amyloses, saccharoses, glucosides, etc., adding H_2O and breaking up their more complex molecules, thus:

Starch,   water,   glucose   cane-sugar,   water,   glucose.
$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6; \text{ and } C_{12}H_{22}O_{11} + H_2O = 2C_6H_{12}O_6.$$

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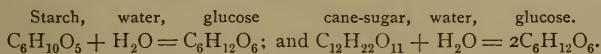
[364] (c) Heat it dry and note that it melts into a yellowish mass, "barley-sugar," and afterwards becomes brown caramel," with some glucose.

[365] (d) Add H_2SO_4 and KHO to successive portions of dry cane sugar and of glucose, and note that the acid blackens the cane sugar first, and the alkali discolors only the glucose.

[366] *Lactose.* Taste it and dissolve it in water, and note its sweet taste and that it responds to Fehling's and other tests for glucose.

[367] *Ferment.* To successive portions of thin starch paste add (a) a few crushed grains of malt.

[368] (b) Some saliva, obtained by chewing paraffine. Towards the end of the hour note the sweet taste and test for glucose.

[369] *Diastase.* To some starch paste in a test-tube add some commercial diastase, and set in water not too warm for the finger to be held in it indefinitely. After a few minutes test for glucose.

[370] *Corn Syrup.* Add 5 Cc. of H_2SO_4 to a beaker of thin starch paste, and boil for an hour, or until a drop ceases to be blued by iodine. Add excess of marble-dust to neutralize the acid and filter. Note its sweet taste; test a portion for glucose; evaporate the rest to a syrup, and allow it to cool. Note that it does so promptly and perfectly as cane-sugar.

[371] "*Shirt-tail sugar.*" Let the demonstrator boil some rags with dilute (5 per cent.) H_2SO_4 for several hours, and at the laboratory hour neutralize with marble dust, filter and distribute to the students to test for glucose.

Vast quantities of glucose are made commercially by boiling amyloses, such as starch,[370] or even cellulose[371] with dilute sulphuric acid. Unless the cheap acid used be contaminated with lead, arsenic, etc., this artificial glucose (corn-sugar)[370] is as valuable for food as the natural. Glucose is sometimes called dextrose from its turning polarized light to the right. It is a strong reducing agent, upon which fact depend most of its tests (for these tests see article on urine).

LAEVULOSE occurs in fruits, etc. in association with glucose, and differs from it in turning the ray of polarized light to the left (hence its name). It may be obtained pure by separating it from the glucose of the invert-sugar made by heating cane-sugar with acids.

Glucosides.

This group includes a numerous class of substances, mainly of vegetable origin, mostly soluble in water and in alcohol; and though differing greatly among themselves, possessing one common property, viz.: When acted upon by a ferment or a dilute acid, they decompose, producing, among other things, *glucose*.[372] Their chemical constitution is not thoroughly understood, but probably they are ethers of glucose. They generally have marked physiological action, and are therefore the active principles of the drugs in which they occur. Their names generally refer to their origin and terminate with "-*in*." A few of the most important are:

AMYGDALIN, found in the bitter almond (amygdala), in the leaves of cherry laurel, and in the seeds of peaches, cherries and plums, associated with an albuminoid ferment, *emulsin* or *synaptase*, which in the presence of heat and moisture decomposes the amygdalin into hydrocyanic acid, benzaldehyde and glucose.

SALICIN is the bitter principle in the bark of the willow (*salix*). It has been employed as a substitute and adulterant of quinine, from which it may be known by the blood-red it gives with sulphuric acid.

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[372] Boil 1 Gm. of salicin for 15 minutes in 10 Cc. of dilute (5 per cent.) H_2SO_4, and neutralize with excess of marble dust. Filter and test for glucose.

TANNIN. This, in several varieties, constitutes the active principle of vegetable astringents. Having an acid reaction and combining with various bases, organic and inorganic, it is often called tannic acid. With gelatin it forms an insoluble and imputrescible compound; hence used from time immemorial to tan leather. It precipitates various metals, especially iron, with which it forms a blue-black, much used in inks and dyes, and making all vegetable astringents incompatible with solutions containing iron.

MYRONIC ACID exists in black mustard, associated with myrosin, an albuminous ferment capable of converting the myronic acid into glucose and allyl sulphocyanate, to which latter the mustard owes its virtue. Hot water, by coagulating this ferment, renders a mustard plaster inert.

INDICAN occurs in various plants, the *indigofera;* also in urine, being derived from indol, a weak base produced by the pancreas and taken up from the alimentary canal. It is a brownish, bitter, syrupy liquid, which, when fermented or treated with dilute acid, forms indigo-blue and a kind of glucose.

Other important glucosides are: *Arbutin, cathartic acid, colocynthin, digitalin, elaterin, gentianin, glycyrrhizin* (from licorice), *jalapin, santonin, saponin, solanin,* etc.

Bodies of the Ammonia Type.

Taking the molecule of ammonia, NH_3, as a basis, and by substituting for one or more atoms of its hydrogen one or more organic radicals or combinations of radicals, we can obtain a large number of interesting and important substances; and the number is still further increased by polymerism, *i. e.*, the faculty of the molecules duplicating themselves, so that one set of compounds may be formed on the type of NH_3 and another on that of N_2H_6, and so on. Many of these substances have trade names alluding to some use or property, or in abbreviation of their chemical names, but their use is almost without excuse, as we have for them a very complete and systematic chemical nomenclature, the most

satisfactory, perhaps, in all chemistry. They bear the names of the radicals entering into their own composition, and end in "*–amine,*" when those radicals are electro-positive, or in "*-amide,*" when electro-negative and containing oxygen. For example :

Amines—

Ammonia.   Ethylamine.   Phenylamine.   Trimethylamine.

$N \begin{cases} H \\ H; \\ H \end{cases}$ $N \begin{cases} C_2H_5 \text{ (ethyl)} \\ H \\ H \end{cases};$ $N \begin{cases} C_6H_5 \text{ (phenyl)} \\ H; \\ H \end{cases}$ $N \begin{cases} CH_3 \text{ (methyl)} \\ CH_3 \quad " \\ CH_3 \quad " \end{cases}$ etc.

Like ammonia, these bodies are alkaline, and combine with acids to form salts, appropriating instead of displacing their hydrogen, *e. g.* $NH_3 + HCl = NH_4Cl$, ammonium chloride or ammonia hydrochloride ; in like manner $NH_2(C_2H_5)+HCl = NH_2(C_2H_5)HCl$, ethylamine hydrochloride.

Amides—

Ammonia (Amine).   Acetamide.   Acetanilide. (Phenyl Acetamide).   Carbamide (Urea).

$N \begin{cases} H \\ H; \\ H \end{cases}$ $N \begin{cases} H \\ H \\ C_2H_3O \text{ (acetic rad.)} \end{cases};$ $N \begin{cases} H \\ C_2H_3O \\ C_6H_5 \text{ (phenyl)} \end{cases};$ $N \begin{cases} H \\ H \\ N \begin{cases} H \\ H \end{cases} \end{cases} > CO$

ANILINE,[373] $N \begin{cases} C_6H_5 \\ H \\ H \end{cases}$ phenylamine, amidobenzene, made by the action of nascent hydrogen (from HCl and iron filings) on nitrobenzene. It is a colorless liquid, but its compounds, the aniline dyes, are coloring matters of great brilliancy.[374-376]

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[373] *Aniline from acetanilide.* Crush together 1 Gm. each of NaHO and acetanilide; warm in a test-tube until they coalesce. Then invert the test-tube and continue heating as long as oily globules of aniline run out. Gather these in another test-tube and compare with the commercial article.

Acetanilide.   Aniline.   Sodium acetate.
$$(C_6H_5)NH(C_2H_3O)+NaHO = C_6H_5NH_2 + NaC_2H_3O_2.$$
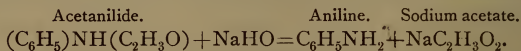
[374] *Rosaniline.* To about 2 Gm. of $HgCl_2$ add 3 drops of aniline, and warm until it turns green and then purple. When cool, add a little alcohol and a drop or two of HCl. Stir into a beaker of water, and note the purple rosaniline hydrochlorate.

[375] *Nitro aniline.* Shake a drop of aniline in a test-tube of dilute H_2SO_4; mix a few drops of this with a few drops of strong H_2SO_4 in a porcelain dish, and then add a trace of nitric acid, and note dark red color; a delicate test for nitric acid.

When taken or inhaled, aniline is an active poison, but some of its salts have found a place in therapeutics, especially the sulphate ; one grain doses for chorea and epilepsy.

TRIMETHYLAMINE is sometimes confounded with propylamine. $N \begin{cases} CH_3 \\ CH_3 \\ CH_3 \end{cases}$ It is a colorless, volatile alkaloid, with an ammoniacal, fishy odor. It is found in many animal and vegetable substances, but is obtained from pickled herring. The hydrochloride is the salt used. Dose, ten to fifteen grains.

ACETANILIDE.—This is a derivative of aniline, in which the acetic $N \begin{cases} C_6H_5 \\ H \\ C_2H_3O \end{cases}$ radical, minus O, is made to displace an atom of hydrogen. A crystalline, odorless solid, slightly soluble in warm water, very soluble in alcohol ; made by the action of glacial acetic acid on aniline. In doses of five to ten grains, repeated every two or three hours, it is an antipyretic and sedative. It is said not to affect the healthy temperature, but to rapidly lower a fever. Its copyright name is "antifebrin."

Test: a yellow-green color with a green fluorescence when heated for some time with an equal weight of zinc chloride.

PHENACETINE.—The formula shows that this substance is closely $N \begin{cases} C_6H_4—O—C_2H_5 \\ H \\ C_2H_3O \end{cases}$ allied to acetanilide. A white crystalline powder, only slightly soluble in water. In doses of fifteen grains it causes a fall of temperature and a profuse sweat. Its effect is more persistent, and perhaps more dangerous than antipyrine, and may produce symptoms of aniline poisoning with hæmoglobinuria and jaundice, especially if an impure drug be used. Like acetanilide, it is used as a substitute for iodoform on painful ulcers, relieving pain and promoting healing.

ANTIPYRINE, $C_{11}H_{12}N_2O$, a derivative of the artificial alkaloid, chinoline, is a white crystalline powder, soluble in water and in

[376] Dissolve a few drops of this anilin in water in two test-tubes. To one add solution of chlorinated lime—a purple color is produced; to the other add some sulphuric acid and potassium chromate mixture—a blue color appears.

alcohol, of a slight tarry taste and odor. With nitrous acid, it forms a green precipitate, and is therefore incompatible with spirits of nitrous ether. This green color is a test, not only for antipyrin, but for the presence as well of nitrous ether, *e. g.*, in any specimen of "sweet spirits of nitre." In doses of ten to fifteen grains it is a valuable antipyretic and anodyne. The hydrochloride is the salt used.

Proteids.

The name proteid is given to a numerous and varied class of bodies in allusion to their occupying first (*protos*, first) rank among the proximate principles of animal and vegetable tissues. They are all highly nitrogenous, and are the only substances capable of living. They originate only in plant life, and are appropriated by animals and constitute the major part of the solid portion of their tissues and fluids, except the sweat, urine and bile. Their ultimate analysis shows about 50 per cent. carbon, 7 per cent. hydrogen, 23 per cent. oxygen, 16 per cent. nitrogen and 4 per cent. sulphur. The empirical formula, $C_{72}H_{112}N_{18}SO_{22}$, has been suggested; but of their rational formula we know almost nothing, except that their molecules must have great weight and complexity. They are amorphous, colorless, odorless, colloid (uncrystallizable) bodies; and, except peptones, are not osmotic —do not dialyze—do not diffuse through animal membranes. Some are soluble, others insoluble. Some are rendered insoluble by heat or by certain acids, alcohols and metallic salts, these serving as tests for the proteids, and the proteids as antidotes to them.

Tests :—(1) They are all precipitated by alcohol, and, in time, coagulated.

(2) Heated with strong nitric acid (xanthoproteic test) they turn yellow, owing to the formation of xanthoproteic acid ; and on the addition of an alkali, become orange.

(3) Biuret test: Add a few drops of dilute copper-sulphate solution and an excess of KHO ; a violet color appears.

(4) Millon's reagent colors the proteids purple-red on heating. This reagent is composed of mercury one part, nitric acid one parts, plus two volumes of water.

Classification of the Proteids :—The physiologists divide the proteids into eight classes ; 1, native albumins ; 2, globulins ; 3, derived albumins ; 4, fibrins ; 5, peptones ; 6, albumose ; 7, coagulated proteids ; 8, lardacein. The latter (lardacein) is an amyloid substance found as a pathological infiltration in various organs.

1. NATURAL ALBUMINS are so called because they occur naturally in the blood, lymph, chyle, etc., also in the whites of eggs and in plants. Natural albumins comprise (*a*) serum albumin, (*b*) egg albumin, (*c*) vegetable albumin.

As a class these albumins are soluble in water ; not coagulated by dilute acid unless heated above 167 F. ; coagulated by strong acids and by heat.

Serum albumin in solution is a white or pale yellow fluid,[377] slightly alkaline, and is coagulated by heat and by acids. It is not readily coagulated by alcohol or ether.

Egg albumin (found in solution in the white of egg)[378] is coagulated by ether and very rapidly by alcohol ; otherwise has the same characteristics as serum albumin.

Vegetable albumin (found in nearly all vegetable juices) is co agulated by heat and by acids.

Paralbumin and *Metalbumin*, found in ovarian cysts, belong to this class of natural albumins.

2. GLOBULINS are, as a class, insoluble in pure water ; soluble in dilute but precipitated by strong sodium chloride solution ; coagulated by heat, and precipitated when carbon dioxide gas is passed through them.

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[377] *Preparation of Serum Albumin.* May be easily obtained from blood, from which it separates in coagulation, but is sold dried for calico printing and sugar refining.

[378] *Preparation of Egg Albumin.* Through a small hole in the end of an egg pour out the white, leaving the yolk in the shell. Break up the white with a glass rod and strain through wet muslin.

Globulins comprise (*a*) *para-* or *serum-globulin*, found in blood-serum and in lymph ; (*b*) *fibrinogen* found in blood-plasma, lymph, chyle, etc. ; (*c*) *myosin*,[379] found in muscle, and, by its coagulation, responsible for the condition known as rigor mortis ; (*d*) *crystallin*,[380] found in the crystalline lens ; (*e*) *vitellin*,[381] found in the yolk of egg.

3. DERIVED ALBUMINS (albuminates) are as a class insoluble in water and in dilute sodium chloride solution, but soluble in dilute acids and alkalies ; not coagulated by heat. Derived albumins comprise : (*a*) *acid albumin*,[382] formed by treating natural albumin with dilute acid (HCl) for a considerable while ; (*b*) *syntonin*,[383] made by digesting myosin with weak HCl, and precipitating with an alkali, when it appears as a pasty, whitish mass ; (*c*) *alkali albumin*, made by treating natural albumin with an alkali ;[384] is slightly soluble in water and in sodium chloride solution, differing therefore from acid albumin ; (*d*) *casein*, made by diluting milk with four volumes of water and acidulating with acetic acid until the milk contains about $\frac{1}{10}$ per cent. ; (*e*) *Legumin* (vege-

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[379] *Preparation of Myosin.* Chopped lean beef is soaked in water, and the water expressed through a cloth, and the process repeated until all albumin is removed. The residue is then soaked in 10 per cent. salt solution, which when expressed is found to contain the myosin.

[380] *Preparation of Crystallin (globulin).* Grind up with 10 Cc. of water in a mortar, the crystalline lens of an ox, and filter off the water, which removes the albumin. Rub up the residue with 10 Cc. of 10 per cent. salt solution which dissolves the crystallin.

[381] *Preparation of Vitelin.* Wash the yolk free from the white, and shake it with ether in a test-tube to remove the fats. Pour off all the ether possible, and let the rest evaporate. Impure vitellin remains. Water does not dissolve it, though salt water makes a milky solution.

[382] *Preparation of Acid Albumin.* Stir 20 drops of glacial acetic acid with the white of one egg until it forms a gelatinous mass of acid albumin. This is then dissolved in a beaker of warm water for use.

[383] *Preparation of Syntonin.* Chopped beef is repeatedly soaked in water, and the water expressed to remove the serum albumin. The residue is then digested in a 0.2 per cent. solution of HCl, and the solution expressed contains the syntonin or muscle acid-albumin.

[384] *Preparation of Alkali Albumin.* With the white of one egg, stir 3 Cc. of KHO solution. Dissolve the gelatinous mass in a beaker of water to use as a solution of alkali albumin.

table casein), found in the seeds of peas and beans, also in almonds, and reacting like milk casein.

4. FIBRINS are, as a class, insoluble in water, difficultly soluble in strong acids and alkalies, whereby they are changed to derived albumins; coagulated by heat. Fibrins comprise (*a*) *blood fibrin;* produced by the action of fibrin ferment upon the fibrinogen and fibrinoplastin of blood, lymph, chyle, etc., whereby a clot is formed; insoluble in water, alcohol or ether, but slowly soluble in dilute acid; (*b*) *Glutin* (vegetable fibrin) existing in vegetables and probably a mixture of several proteids; insoluble in water, alcohol or ether.

5. PEPTONES, as a class, are soluble in water, acids, alkalies and sodium chloride solution. They are precipitated by alcohol, tannic acid, bichloride and potassium-mercuric chloride. With $CuSO_4$ solution (a few gtt.) and KHO in excess, peptones give a red color. Pepsin of the gastric juice and the trypsin of pancreatic juice, in the process of digestion, act upon proteids to convert them into peptones, which are diffusible (osmotic).

6. ALBUMOSES are soluble in dilute sodium chloride solutions and in water, give a red color, as do the peptones, with $CuSO_4$ and an excess of KHO. Albumoses are intermediate between acid-albumin and peptone.

7. COAGULATED PROTEIDS are as a class, insoluble in water, sodium chloride, dilute or alkali. They are the result of the action of heat, acids, alcohols, etc., on true albumins or globulins.

8. LARDACEIN, as stated above, is found as an amyloid infiltration in various organs and tissues in persons long suffering from wasting disease. In composition, it is a proteid, but is not digested by pepsin and HCl and with iodine it strikes a red; or a blue, if previously treated with sulphuric acid.

Alkaloids.

ALKALOIDS (alkali-like) are *organic alkalies,* a class of bodies of alkaline reaction and capable of neutralizing acids and forming with them distinct and crystallizable salts. They are undoubtedly *amines* or *amides, i. e.,* ammonia in which one or more atoms of

hydrogen in the molecule, NH_3, are replaced by one or more organic radicles or combinations of organic radicles, but the molecules seem to be far more complex than those artificial alkaloids. Of late years chemists have made a number of amines, some of them similar, if not identical with certain natural alkaloids; and the time seems not far distant when our most costly and complex alkaloids will be made artificially; in fact, all that seems to prevent it now is not knowing the exact constitution of such complex molecules. In plants alkaloids are not found free, but combined with some vegetable acid forming a salt. Their salts (except tannates) are usually soluble and intensely bitter; the free alkaloids, being much less soluble, are much less bitter. Those alkaloids (as conine and nicotine) that contain no oxygen are liquid; but the great majority of them are white powders.

Alkaloids are so seldom prescribed in the free state that when the simple name of an alkaloid is written in a prescription the druggist puts up its most common salt. The names of alkaloids end in "-ine," and are derived from the names of the plants in which they exist or from some characteristic property.

The intense effect alkaloids exert on the animal organism makes them generally the active principles of the drugs in which they are found. But the active principle of a drug is not always an alkaloid. The alkaloids include the majority of our most potent remedies and powerful poisons. Tannin is a common antidote, but most important is the prompt evacuation of the stomach and the intelligent use of physiological antagonists.

The alkaloids, even those of medical interest, are so numerous that to give each separate consideration would cover a great portion of the materia medica. We can mention but a few of the most important. See Table, page 178.

PTOMAÏNES *are putrefactive alkaloids.*—The word "ptomaïne" was first used by an Italian, Francesco Selmi, who discovered in decomposing organic matter certain basic, alkaloidal bodies. He recognized their resemblance to the vegetable alkaloids, and called them in contradistinction ptomaïnes ($\pi\tau\tilde{\omega}\mu\alpha$, a corpse) or cadaver

alkaloids.   Later study has taught us that the various bacteria act upon organic matter, and with the requisite amount of heat and moisture, cause its decomposition with the production of pto- maines.   As a rule, bacteria will cause these putrefactive changes only in dead animal or dead vegetable matter, but in pathological states it is possible for germs to flourish and multiply in the living organism, causing the same putrefaction, and hence the same pro- duction of ptomaïnes.   The different bacteria produce different ptomaïnes; thus the typhoid bacillus produces *typhotoxine*, the tetanus bacillus produces *tetanine*.   It is generally accepted to- day that the symptoms of infectious diseases and specific fevers are due solely to the poisons produced by bacterial growth in the living organism ; and since analogous conditions and symptoms may be brought about by the administration of the ptomaïne ob- tained from any given bacteria, this view is evidently correct.

The poisoning that frequently results from eating spoiled meat, fish, etc., is due to ptomaïnes.   The symptoms of poisoning by ptomaïnes resemble those by the vegetable alkaloids, except that there is usually more gastro-intestinal irritation.   The resemblance of the physiological effects and chemical tests to those of such alkaloids as strychnine, morphine, conine, nicotine, atropine and veratrine, is apt to, and doubtless has often led to the escape of the guilty and the condemnation of the innocent.   Among the poisonous ptomaïnes may be mentioned, besides typhotoxine and tetanine, *tyrotoxicon*, a very poisonous alkaloid, discovered and described by Vaughan.   It is found in spoiled milk and in ice cream and cheese made from it.   Tyrotoxicon poisoning is char- acterized by a chill, with nausea and vomiting, epigastric pains, griping, purging and perhaps collapse and death. *Spasmatoxine* is obtained from the bacillus of tetanus, and like tetanine, which is obtained from the same bacillus, produces decided convulsions.

Other poisonous ptomaïnes are, *isoamylamine*, a very poison- ous, and rapidly fatal alkaloid, found in decomposing yeast and in cod-liver oil ; *tetanotoxine, susotoxine, neurine, coline* and *mus- carine* (obtained from poisonous mushroom), are decidedly poisonous ptomaïnes.

Among the non-poisonous ptomaines may be mentioned : Neuridine, methylamine, trimethylamine, ethylamine and diethylamine, pyocyanine (from bacillus pyocyaneus), mydine, etc.

Putrescine and cadaverine are only slightly poisonous. Since some ptomaïnes are not poisonous and others are decidedly toxic, it has been considered best to invent the term "toxines" for the poisonous ones.

LEUCOMAÏNES are a class of alkaloidal substances produced in the living body as a result of fermentative changes or of the processes of retrograde metamorphosis, as, for example, urea. They are eliminated in the various excreta. If retained, as in uræmia, or produced in abnormal quantity, as in dyspepsia, they act deleteriously on the nerve-centers, causing vertigo, lassitude, drowsiness, vomiting, purging and coma. Some elevate, while others lower the temperature. Of the more important leucomaïnes may be mentioned : Kreatine, kreatinine, xanthine, hypoxanthine, paraxanthine, heteroxanthine, pseudoxanthine, spermine, salamandarine, etc. Most of the leucomaïnes are non-poisonous ; some few are decidedly toxic.

BACTERIAL PROTEIDS.—Very little is known of bacterial proteids since they quickly decompose. The bacterial proteid poison of diphtheria, of tetanus, of cholera and of typhoid have been isolated. These proteids, or toxalbumins, as they are sometimes called, are formed by the action of bacteria on albuminous material ; and their effect upon the animal organism, when administered internally or hypodermatically, is to produce symptoms identical with those of the bacterial infection.

ANTITOXINE.—A few words must be said about antitoxines : It has been found that when an animal has recovered from certain infectious diseases, there is present in the serum of that animal's blood something which confers partial or complete immunity to the animal against further attacks from the same disease ; and this serum, when injected into other animals exhibits the same protective power. The composition of this substance is unknown, but on account of its antitoxic effects it has been called antitoxine. We have already a diphtheria antitoxine, a tetanus

antitoxine, a streptococcus antitoxine, etc. Clinical results have shown conclusively that a new field of therapy is open here to the physician. Let us hope that this "serum-therapy of Behring" will do as much in other infectious diseases as has already been accomplished in variola by Jenner's discovery of vaccine.

TABLE OF COMMON ALKALOIDS.

NAME.	FORMULA	SOURCE	REMARKS.
Morphine	$C_{17}H_{19}NO_3$	Opium	Crystalline; morphia gives a blue with $FeCl_3$, and a red with HNO_3. These alkaloids and several others exist in opium in combination with meconic acid, which gives with Fe_2Cl_6 a red color not discharged by $HgCl_2$.
Codeine	$C_{18}H_{21}NO_3$	"	
Narcotine	$C_{22}H_{23}NO_7$	"	
Narceine	$C_{23}H_{29}NO_9$	"	
Apomorphine	$C_{17}H_{17}NO_2$	Morphine	Made by heating morphine with HCl; a systemic emetic.
Quinine	$C_{20}H_{24}N_2O_2$	Cinchona bark	All crystalline except quinoidine, which is a resinous mass. To test for quinine, add chlorine water, shake, and then add aq. ammonia; a green color.
Quinidine	"		
Quinicine	"		
Quinoidine	"		
Cinchonine	$C_{19}H_{22}N_2O$		
Cinchonidine	"		
Cinchonicine	"		
Strychnine	$C_{21}H_{22}N_2O_2$	Nux vomica	Crystals; gives a purple with H_2SO_4 $K_2Cr_2O_7$ or MnO_2.
Brucine	$C_{23}H_{26}N_2O_4$	"	Crystals; gives a red with HNO_3.
Aconitine	$C_{30}H_{47}NO_7$	Aconite	Crystals; very poisonous.
Colchicine	$C_{17}H_{19}NO_5$	Colchicum	
Veratrine	$C_{32}H_{52}N_2O_8$	Veratrum	
Atropine	$C_{17}H_{23}NO_3$	Belladonna	Crystals; used to dilate the pupils.
Hyoscyamine	$C_{15}H_{23}NO_3$	Hyoscyamus	
Homatropine	$C_{16}H_{22}NO_3$	Atropine	
Hyoscine	$C_{17}H_{21}NO_4$	Hyoscyamus	Sedative and hypnotic; crystals.
Caffeine	$C_8H_{10}N_4O_2$	Coffee	Crystals; soluble in water.
Theine	"	Tea	Crystals; soluble in water.
Theobromine	$C_7H_8N_4O_2$	Chocolate	Stimulant, crystals.
Cocaine	. . . .	Coca leaves	Crystals; soluble in water; weakly basic; local anæsthetic.
Physostigmine (Eserine)	$C_{15}H_{21}N_3O_2$	Physostigma (Calabar bean)	Crystals; contracts the pupils.
Pilocarpine	$C_{11}H_{16}N_2O_2$	Jaborandi	Crystals; a powerful diaphoretic.
Urea	CH_4N_2O	Urine	Crystals; may be made artificially by heating NH_4CNO.
Nicotine	C_5H_7N	Tobacco	Liquid; powerful poison.
Conine	$C_8H_{15}N$	Hemlock	" " "

PART III.—CLINICAL CHEMISTRY.

THE URINE.

THE urine is a fluid secreted continuously by the kidneys, and is the chief means by which the nitrogenous waste of the body is discharged.[385]

A specimen, to be representative, should be a portion of the whole twenty-four hours urine, for considerable variation in com-

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[385] The rationale of its secretion is one of transudation, osmosis, and elaboration. Owing to the resistance encountered by the blood in its exit through the efferent vessel, there is an increase of blood pressure in the Malpighian tuft and a transudation of the water of the blood with some dissolved salts into the capsule. From loss of water the blood is very much thickened when it reaches the second capillary system surrounding the convoluted tubes, which contain the thin, watery transudation from the Malpighian bodies. Here are the essential elements of a complete osmometer—an animal membrane, composed of the thin wall of the capillary and the delicate basement membrane of the tube, with a dense fluid (the thickened blood) on one side and a thin saline solution on the other. An interchange now takes place of the water from the tube to the blood, and of the products of retrograde metamorphosis (urea, etc.), and salts from the blood to the tubes, concentrating the fluid in the latter, making it urine, while the albuminous constituents of the blood, not being osmotic, are retained. An elaborative function has long been attributed to the epithelial cells lining the convoluted tubes, for it was observed that whenever the tubes lost their epithelial lining (as in some forms of Bright's disease), urea, etc., failed to be eliminated. This function of the cells may be demonstrated by injection into the veins of a rabbit a solution of sulph-indigotate of sodium. If the animal be killed within a few minutes, none of the coloring matter will be found in the capsules, while the cells lining the tubes will be stained blue. If, however, an hour be allowed to elapse, even the cells will be found colorless and the coloring matter will be seen only in the urine. Our conclusion drawn from this is that the production of urine is chiefly an elaborating or secreting process, regulated in its fluidity by the glomerular system; that the water and some of its salts are secreted by the glomeruli, the peculiar anatomical construction of which permits a varying degree of activity corresponding chiefly with the varying degree of blood pressure and blood fluidity; while in the main, the solid excretory products of the urine are elimated by the epithelium of the renal tubules, through their vital, selective or secretory power, as in all other glandular structures of similar anatomical construction.

position and properties may occur during the day. Especially is this true of traces of albumin and sugar. When this is impracticable, that passed before breakfast is generally preferable, because farthest from a meal. When significant variations during the day

FIG. 44.

G. TIEMANN-CO.
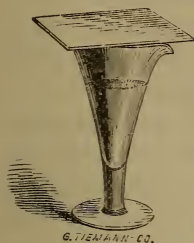
are suspected, several specimens may be taken at different hours. For *microscopical examination*, a few ounces of the urine in a stoppered vial, or covered conical glass, Fig. 44, are set aside for several hours until the sediment, having settled to the bottom, can be examined. A much more improved and satisfactory method is by the use of the centrifuge, as thereby the precipitate can be obtained at once from fresh urine.

Physical Properties.

Normal urine is a *transparent, aqueous fluid, of a pale yellow color, characteristic odor, faint acid reaction, and of a specific gravity of 1020 when passed in the average quantity of about 1500 Cc. (48 fl. ounces) in the twenty-four hours*. This description is to be taken with much allowance, for very wide variations occur even in health. With these variations the student must become thoroughly familiar before he is capable of interpreting a specimen.

Quantity.—In health, the average adult secretes about 1500 Cc. (48 fl. ounces) a day, most in the afternoon and least at night; but the quantity may vary widely (from 500 Cc. to 5000 Cc.) depending upon, (*a*) the quantity of liquids ingested, and (*b*) its vicarious elimination by the skin, lungs and bowels.

In disease, it may be increased (polyuria) or diminished (oliguria) or even suppressed (anuria).

Polyuria occurs in (*a*) diabetes mellitus or insipidus; (*b*) contracted and amyloid kidney; (*c*) pyelitis; (*d*) cardiac hypertrophy; (*e*) after the crisis of acute diseases; (*f*) during rapid absorption of exudates and transudates; (*g*) in nervous excite-

ment, as epileptic and hysterical attacks or even fright and anxiety ; (*h*) after administration of diuretics.

Oliguria occurs in (*a*) fevers and inflammatory affections ; (*b*) acute nephritis ; (*c*) excessive elimination of water by other channels, as in sweating, diarrhœa, etc. ; (*d*) conditions of lowered arterial tension as in heart failure, exhaustion, shock, etc.

Anuria or suppression of urine differs from oliguria only in degree and should not be confounded with *retention*, in which case the urine is secreted, but retained in the bladder.

Transparency.—Normal urine is not always transparent, nor is transparent urine always normal. Some degree of opacity may be due to (*a*) Mucus, which, with entangled epithelial cells, may be observed as a slight cloud in many specimens of healthy urine, especially of females because of the larger area of mucous surface in that sex. This faint cloud may be seen floating at any depth and is unaffected by most chemicals except acetic acid, which may slightly increase the opacity by coagulating the mucin. The mucus is usually removed by filtration ; (*b*) Urates (of Na, K, Ca, and Mg), which often form a precipitate in the urine, especially when allowed to cool, as in standing over night in a cold room. The test for this sediment is heat, which quickly dissipates it. (*c*) Earthy phosphates (of Ca and Mg), which may give an opacity to normal urine if it is alkaline or even ceases to be acid. The test for this sediment is that it promptly clears up, on the addition of a few drops of any acid, while heat would only increase it. (*d*) Fungi (bacteria, penicillia, sarcinae, etc.), especially in decomposing urine.

A urine may be *abnormally* opaque or cloudy from the abovementioned causes, or from the presence of blood, pus, epithelia, tube casts, fat globules,[386] etc. When due to blood, pus or organized detrita, the opacity is increased by heat or acids because of

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[386] In chyluria the urine is mixed with chyle, the fat being in a state of emulsion, and is milky, and if alkaline, is even viscid. I have seen it only a few times in this country, but it is common in the tropics, and is due to the presence of the filaris sanguinis hominis.

the precipitation of albumin which is always present in liquor san-
guinis and liquor puris, and is usually associated with tube-casts,
etc.

Fluidity.—Healthy urine is never otherwise than an aqueous
fluid, flowing and dripping with ease; but in certain diseased
conditions, abnormal quantities of mucus, or the presence of pus
or fat, especially if the urine be allowed to decompose and be-
come very alkaline, may make it more or less viscid.

Color.—Healthy urine is of a pale yellow, or amber color, the
depth of which varies greatly according to the quantity of water
present and the consequent degree of concentration or dilution.
Aside from abnormal degrees of the above, *pathological* variations
in color may be the result of (*a*) a diminution of the normal color-
ing matters, as in anæmia, diabetes and certain forms of kidney
disease; (*b*) an increase of the normal coloring matters, as in
fever and other diseases destructive of blood and tissue; (*c*) by
the presence of abnormal substances, as biliary and blood color-
ing matters.

(*d*) Moreover, the urine may be colored after the administra-
tion of certain drugs, as senna, santonin, rhubarb, carbolic acid,
prickly pear, etc.

Odor—Urine has a charactetistic odor, the strength of which
depends mainly on its concentration. When freshly passed, it
has also an aromatic fragrance, due to certain volatile ethers.
The more concentrated the urine, the stronger the odor because
of the larger quantity of urea it contains.

Diabetic urine exhales a sweetish and fruity smell, owing to the
presence of acetone. In certain forms of dyspepsia and of liver
trouble, the odor of the urine is almost pathognomonic. Medi-
cines and certain articles of food often impart a peculiar odor, as
turpentine the odor of violets, asparagus and cauliflower a rank,
disgusting smell; also cubebs, copaiba, sandalwood-oil, garlic,
tolu and salol, impart their characteristic odors.

Reaction.—Normally the urine of the whole twenty-four hours
will average an acid reaction; but great variations occur during

the day. Before meals it will have a high degree of acidity, but after meals becomes nearly neutral or even alkaline. This is due to the ingestion of food, which is largely alkaline, and to the abstraction of acidulous principles from the blood to form acid gastric juice. It has also been observed that urine passed on rising in the morning is especially acid. This is probably owing to the fact that during sleep less carbonic acid is exhaled from the lungs, and less perpiration (acid) given off by the skin.

The urine is especially acid whenever the albuminoid tissues are being rapidly oxidized as in fever, diabetes, carcinoma, etc. It is especially alkaline after the ingestion of alkaline salts or of neutral salts of vegetable acids and alkali metals, the acidulous radicals of which are oxidized in the blood, so that the salts appear in the urine as carbonates. This explains the alkaline urine of vegetarians and herbiverous animals.

FIG. 45.
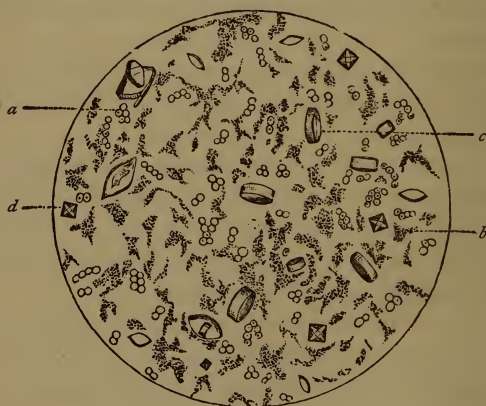
Sediment from a urine in "acid fermentation." (a) Fungus; (b) amorphous sodium urate; (c) uric acid; (d) calcium oxalate.

The reaction of urine is important to the physician, as it may favor or prevent irritations of the kidneys and bladder or the formation of sediments and concretions. The acidity of urine is

due, not to free acid, but to acid sodium phosphate (NaH_2PO_4) occurring in consequence of carbonic, uric and hippuric acids, seizing on to a portion of the sodium of the phosphate (Na_3PO_4). The degree of acidity is best measured by a decinormal alkaline solution (see Acidimetry, page 96).

An *acid fermentation*, attended by a decomposition of mucus and coloring matters and a production of acetic and lactic acids, sometimes occurs in urine that has stood for some at a moderate temperature (Fig. 45). After a while, more quickly in warm weather, the *alkaline fermentation* begins, caused by the development of the micrococcus ureæ (Pasteur). The urea is converted into ammonium carbonate, thus: $(NH_2)_2CO + 2H_2O = (NH_4)_2CO_3$. This gives the urine an ammoniacal odor and alkaline reaction, and it becomes opaque from the precipitation of urate of ammonium (Fig. 46), and the earthy phosphates and the

FIG. 46.

Sediment from a urine in the "alkaline fermentation." (*a*) Ammonium urate; (*b*) ammonio-magnesium phosphate; (*c*) bacterium ureae.

development of bacteria. Pus and blood or vessels tainted with urine previously fermented greatly hasten this change. The reaction is recognized by litmus paper. If acid, the blue litmus is

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turned red ; if alkaline, the red litmus is turned blue ; if neutral there is no change in either. If alkalinity be due to ammonia (volatile alkali) the blued paper gets red again on drying.

Specific Gravity.—Though the average specific gravity is 1020, it exhibits, even in health, great variations, the extremes being 1002 after copious use of water and diuretics, and 1040 after abstinence from fluid and the elimination of water through other means, as profuse perspiration or copious diarrhœa. The amount of solids varying but little in health, fluctuations in specific gravity are due mainly to variations in the amount of water ; so, as long as the inverse proportions between specific gravity and volume of urine is preserved, variations need cause no alarm. Marked departures, however, from this inverse ratio are of the gravest import. A specific gravity too small for the volume of urine indicates renal defect and heralds uræmia ; a specific gravity too high would indicate glycosuria or excessive tissue waste, as in fevers.

FIG. 47.

FIG. 48.
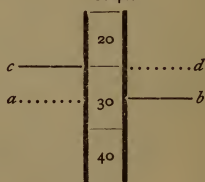
Urinometer.

Diagram.

Specific gravity is usually measured by an instrument called a hydrometer or urinometer (Fig. 47), which is a hollow, glass float, weighted with mercury and having a long, graduated neck. The graduation begins above at 1000, because the heavier the urine

the less deeply will the instrument sink and the further ne neck will protrude from the surface. It is well to test a new urinometer by immersing it in water at 60° F. (15.5 C.), when it should sink to 0, or 1000, on the scale. Urinometers are usually provided with a cylinder, or jar, as shown in the figure, but a large test-tube will answer. This is about three-fourths filled ; the urinometer is then introduced, and when still, the specific gravity is read off. The cylinder or test-tube should not be too narrow, lest the urinometer be attracted to and catch against the sides, and not rise as high or sink as low as it should. One of the best urinometers on the market is Squibb's, in which the jar is sharply fluted inward near the middle and the bulb of the float is made oval so as to present little surface for contact. A thermometer is also provided. For every seven degrees of temperature above the normal (60° F. or 15.5° C.) one degree of specific gravity should be added to the reading. The fluid being attracted up around the stem, the reading should be made not along the line $c\ d$, as in the diagram (Fig. 48) suggested by Dr. Leffmann, of Philadelphia, but along $a\ b$, which represents the true level of the liquid.

To approximate the amount of solids in any urine ; (a) the last two figures of the specific gravity represent the number of grains of solids to the fluid ounce ; (b) doubling the last two figures of the specific gravity, gives the per cent. Thus, if the urine be of the specific gravity 1020, and the daily volume fifty ounces :—(a) 20 (grains per fluid ounce), multiplied by fifty (ounces daily volume) gives 1000 grains of solids per diem ; (b) .020 × 2 = .040 or 4 per cent. which multiplied by fifty (ounces daily volume) gives 2 ounces of solids per diem.

The solids of the urine may be accurately determined by taking a certain volume of urine, e. g., 100 Cc. and evaporating it in a previously weighed porcelain dish over a water-bath, until it no longer loses weight, when it is finally weighed and the weight of the dish subtracted.

Chemical Constituents.

The average composition of a thousand parts of urine is about as follows:

Organic
Water	950.00
Urea..................................	26.20
Kreatine and kreatinine, xanthine and allantoine	.80
Urates of sodium and potassium..............	1.45
Hippurates of sodium and potassium..........	.70
Mucus and coloring matters	.35

Inorganic
Phosphates of sodium and potassium	3.75
Phosphates of calcium and magnesium........	.90
Chlorides of sodium and potassium...........	12.55
Sulphates of sodium and potassium..........	3.30

                                                1000.00

Pathologically there may be present also albumin, glucose, blood, bile, etc., besides various other sediments.

UREA, $N \begin{cases} H \\ H \end{cases} \\ >CO$, or carbamide, is the most constant and $N \begin{cases} H \\ H \end{cases}$
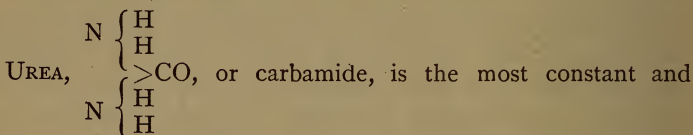
abundant organic constituent of the urine, and being the main nitrogenous excretion, is the index of nitrogenous waste, whether of food or of tissue. Its average amount is about one ounce per diem. Urea may be obtained by extracting it from the urine, or artificially by heating cyanate of ammonium, with which it is isomeric $[(NH_4CNO = (NH_2)_2CO).]$

It crystallizes in colorless prisms, very soluble in water, and behaves like an alkaloid, combining readily with nitric and oxalic acids to form salts. Both of these salts may, by adding nitric or oxalic acid, be precipitated from concentrated urine as colorless, rhombic or hexagonal plates.[387]   (Fig. 49.)

It was formerly believed that the kidneys were the seat of the

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[387] Test for urea. On a glass slide place a drop or two of suspected fluid, add a drop of nitric acid, warm over a spirit lamp; if urea is present the characteristic rhombic or hexagonal crystals of nitrate of urea can be seen with a microscope.

formation of urea, but this has been proved an error, from the fact that after complete extirpation of the kidneys, urea continues to be formed. It is believed now that the liver, and perhaps also the spleen, and the lymphatic and secretive glands, take active part in the formation of urea. Its formation is markedly diminished in degenerative changes in the liver, as in acute yellow atrophy of the liver. Urea is abundantly formed in diabetes; the activity of the hepatic cells being much increased, sugar and urea are formed in great quantities, and after being passed into the blood are excreted by the kidneys. In suppression of the urine, due to diseases of the kidney, the formation of urea continues and is accumulated in the system, giving rise to uræmia. A meat diet increases the quantity of urea and a vegetable diet diminishes it.

FIG. 49.
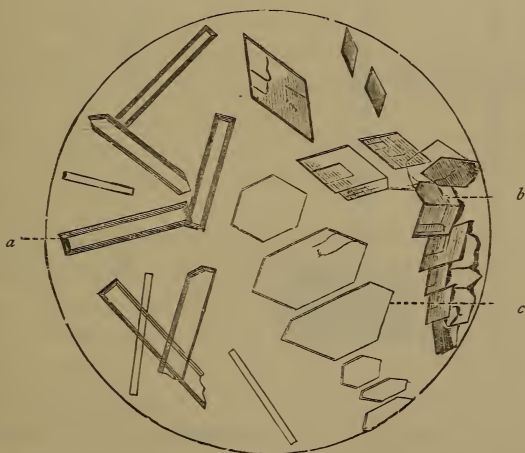
(a) Prisms of urea; (b) hexagonal plates; and (c) rhombic plates of nitrate of urea.

In the course of many diseases it is important to estimate the amount of urea excreted day by day. A rough estimate may be based on the specific gravity. For, since urea is the largest solid ingredient in urine, it follows that if sugar be absent, albumin in

small amount or removed, and the quantity of chlorides normal, variations in specific gravity must be due mainly to variations in the amount of urea.

The exact methods most generally employed consist in decomposing the urine into nitrogen and carbon dioxide, by means of sodium hypochlorite or hypobromite, and measuring either the volume of gas evolved or the specific gravity lost by the decomposition.

Davy's Hypochlorite Method.—A graduated tube closed at one end is one-third filled with mercury. A measured quantity of the urine (a drachm or half drachm, according to capacity of tube) is then added, and the tube is next filled to the brim with the

FIG. 50.   FIG. 51.
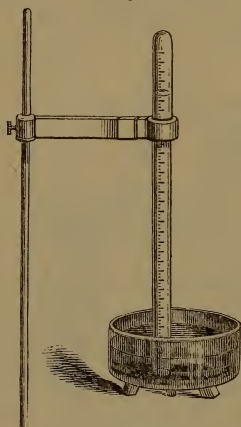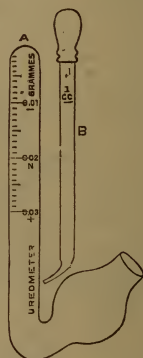
Davy's.   Doremus'.

hypochlorite solution (liq. sod. chloratæ, U. S. P.). Closing the opening with the thumb, the tube is inverted over a strong solution of common salt in a dish (Fig. 50). The mercury runs out and the salt water rises to take its place, while the urine and soda mixture, being lighter, remain in the upper part of the tube. Here the gas from the decomposing urea collects. The decomposition is complete in three or four hours, when the amount of

the gas may be read off by the graduations upon the tube, every cubic inch representing .64 grain (or 1 cubic centimetre representing 2.5 milligrams) of urea. This method is now but little used.

Doremus' Hypobromite Method.—The sodium hypobromite is prepared by adding 1 cubic centimetre of bromine to 10 cubic centimetres of sodium hydrate solution (100 grammes to 250 cubic centimetres of water, or 6 ounces to one pint) and diluting with 10 cubic centimetres of water. Tilt the ureometer (Fig. 51), and pour the hypobromite into the long arm, completely filling it. Draw the urine to be tested into the pipette to the graduation. Pass the pipette into the ureometer as far as the bend, and compress the nipple slowly. The urine will arise through the hypobromite, and the gas evolved will collect in the upper part of the tube. The ureometer is graduated to indicate either the number of milligrams of urea to the cubic centimetre of urine or the number of grains to the fluid ounce. This method is so quick and simple that it is the one generally employed by physicians.

Squibb's Apparatus is similar to the foregoing, but has the advantage of employing the easily obtained liquor sodæ chloratæ U. S. P.

Fowler's Method.—The specific gravity of the urine is carefully determined as well as that of the liq. sodæ chloratæ (U. S. P.) to be used. One volume of the urine is mixed with exactly seven volumes of the liq. sod. chlor. and set aside for two hours, or until effervescence ceases. The specific gravity is again taken. As the reaction begins immediately on mixing the fluids, the specific gravity of the mixture must be determined by calculation. This is done by adding to the specific gravity of the urine seven times that of the liq. sod. chlor. and dividing the sum by eight. Each degree of difference in specific gravity of the mixture before and after the decomposition represents three and a half grains of urea to the fluid ounce of the day's urine, or seven grams to the liter.

Example :

Quantity of urine in twenty-four hours................   46 oz.
Sp. gr. of the urine   1020
Sp. gr. sod. chloratæ   1042
(Calculated) sp. gr. mixture ($\frac{1042 \times 7 + 1020}{8} =$)......   1039.2+
(Actual) sp. gr. mixture after reaction................   1036.2

1939.2— 1036.2 = 3 ; 3 × 3½ = 10½ grs. of urea to the ounce of urine ; 10½ × 46 = 483 grs. of urea passed in the twenty-four hours.

KREATINE AND KREATININE, occur in normal urine, but so sparingly as to be of little practical importance. They are closely allied chemically and physiologically with urea ; appearing in acid urine as kreatinine, $C_4H_7N_3O$, and in alkaline as kreatine, $C_4H_9N_3O_2$, differing in composition only by the molecule, H_2O.

Xanthine and Allantoin are substances closely allied to uric acid ; occur in normal urine so sparingly as to be of little practical importance, and need only be mentioned in this connection.

URIC ACID ($H_2C_5H_2N_4O_3$), formerly called lithic acid, is found in the urine of carnivora : in that of herbivora it is largely replaced by an analogous substance—hippuric acid. Gout is characterized by an increased production of uric acid, and the so-called " chalk-stone " deposit in the joints during that disease is sodium urate. Free uric acid is so very insoluble that whenever it exists in urine it is always a precipitate. It appears as minute reddish grains, which under the microscope are seen to be modifications of rhombic crystals, always stained with the coloring matter of the urine. They often deviate widely from the typical rhomb, as shown in Figs. 52 and 53, but an experienced eye will readily recognize them. Normally, uric acid as soon as formed unites with the alkaline bases to form urates. These are very soluble in warm water, but more sparingly so in cold. Therefore a urine, though clear when freshly passed and warm, may exhibit a copious precipitate upon becoming cold, as on a winter night. This precipitate is easily recognized by its dis-

solving upon warming. Urates of sodium and magnesium gener-
ally appear under under the microscope as amorphous powders
in moss-like aggregations, but occasionally as bundles of small

Fig. 52.
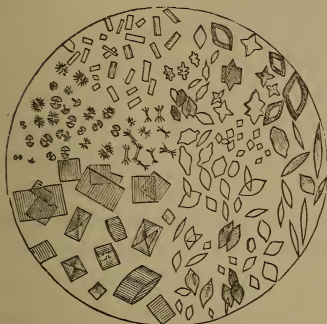
Uric acid.

Fig. 53.

Uric acid.

needles, as shown in Fig. 54. The urate of ammonium, a result
of the alkaline fermentation, occurs as opaque, brown spherules,
smooth or with spiculæ like a thorn apple (Fig. 46).

Fig. 54.
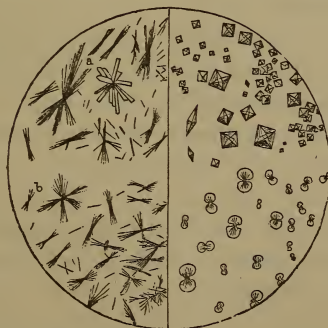
Urates in bundles of small needles.   Calcium oxalate.

Uric acid, being dibasic, can form both normal and acid salts.
If much acid is present in a urine, the normal urates give up one

atom of their metallic base and become acid urates. These are less soluble than the normal, and often precipitate when the urine is very acid [see Fig. 45 (*b*)] or when an acid is added, as in the nitric acid test for albumin.

The *murexid test* for uric acid and the urates is one of great beauty. Place some of the sediment in a porcelain dish, add a drop or two of nitric acid, and carefully evaporate almost to dryness. Add a few drops of ammonia; or, better still (Earp) invert the dish over another in which a dry ammonium salt is volatilized. If uric acid is present, a beautiful purple color will appear.

COLORING MATTERS.—Our unsatisfactory knowledge of these substances and their clinical significance is to be regretted, since some of them possess an importance next to albumin and sugar. The existence of at least two distinct substances has been demonstrated:

1. *Urobilin* (*Urohæmatin*), a brown, resinous substance, derived from the coloring matter of the bile, and hence indirectly from the coloring matter of the blood.

It occurs in normal urine, and in larger quantity in the urine of patients suffering from any disease which causes disintegration of the blood copuscles.

1. *Uro-indican* (uroxanthin) a substance closely related to, but not identical with, the glucoside *indican*, and, like that substance, capable of conversion into indigo-blue. It seems to be derived from the indol formed in the fermentation of albuminous matters, especially in the alimentary canal. It is therefore increased in obstructive troubles and in certain diseases characterized by decomposition of albuminoids or impairment and perversion of general nutrition; so that its presence is not pathognomonic of any one disease.

To roughly estimate the coloring matters, put the urine in a beaker and render it strongly acid with nitric or hydrochloric acid. Let it stand six hours for the color to be developed. Then note the depth of color by transmitted light.

A striking method, especially for indican, is that of Jaffé. Take equal quantities of the urine and fuming HCl, and then add drop by drop with constant stirring, a fresh sat. sol. of calcium hypochlorite until the maximum of blue is produced. This is then shaken with chloroform, which seizes the freshly-formed indigo and soon settles to the bottom as a blue liquid, the depth of color indicating the amount of indican in the urine.

PHOSPHATES.—The phosphates are derived mainly from the food, but to some extent also from oxidation of phosphorized tissues :

1. *Earthy Phosphates* (Ca and Mg).—Being soluble only in acid solutions, the earthy phosphates are precipitated when the urine is made or becomes alkaline. Furthermore, being less soluble in warm than in cold urine, heat often precipitates them, as in the heat test for albumin. Deposits of calcium and magnesium phosphates are generally amorphous, and may be distinguished from the amorphous urates, (*a*) by absence of color and by not gathering in mossy forms ; (*b*)· by a drop of acetic acid added to the sediment on a glass slide under the microscope—phosphates dissolve, while urates gradually lose their base and assume the characteristic forms of uric acid. In ammoniacal urine (alkaline fermentation) the ammonio-magnesium phosphate ($MgNH_4PO_4$), the so-called *triple phosphate* is formed and deposited in large prismatic, coffin-lid crystals ; sometimes also, in ragged stellate or aborescent crystals, resembling those of snow. (Fig. 55.) In cases of cystitis this may occur within the bladder ; hence other calculi often have one or more white layers of the mixed phosphate.

2. *Alkaline Phosphates*.—These constitute the greater portion of the phosphates, and are made up mainly of *acid sodium phosphate*, with traces of potassium phosphate. Being very soluble, they never form a precipitate.

Tests : (*a*) The *earthy phosphates* may be detected by the addition of any alkali *e. g.* liquor potassæ, and gently warming. The normal amount produces only a whitish cloud, or opalescence.

(*b*) To detect and estimate the *alkaline phosphates* the preceding should be filtered and the filtrate treated with magnesia mixture.   U. S. P.[388]

(*c*) The "*total phosphates*" are best detected and estimated

FIG. 55.

Ammonio-magnesium Phosphate.

by precipitation with the magnesia mixture. If the precipitate is thick and creamy, the phosphates are increased; if milky, they are normal; and if translucent, they are diminished.

(*d*) *Centrifugal Test.*—Fill graduated tube to 10 Cc. mark with fresh urine; add 5 Cc. of magnesia mixture, mix and then rotate for three minutes at the usual speed of one turn of the handle to the second.   Normally the sediment should occupy ten per cent.

Pathologically the phosphates are decreased in gout and most inflammatory diseases, especially in nephritis.   This is a very valuable and almost constant symptom.   They are increased in wasting diseases of the osseous and nervous systems and markedly so in the so-called "phosphatic diabetes," a disease attended by the various symptoms of denutrition.

CHLORIDES.—These, normally about 15 Gm. a day, consist

[388] *Magnesia Mixture*, U. S. P.   Magnes. Sulph., 10 Gm.; Ammon. Chloride, 20 Gm.; Water, 80 Cc.; Ammonia water, 42 Cc.

almost entirely of sodium chloride, the quantity depending mainly on what is taken in with the food. However, in many fevers, especially in pneumonia, the chlorides may be diminished in the urine or may even disappear from it, much being eliminated by sputa. Their reappearance in the urine is often the earliest indication of convalescence. Hence their detection and estimation are important.

Silver-Nitrate Test.—First add a few drops of nitric acid to prevent the precipitation of the phosphates. Then, on adding silver-nitrate solution (1 to 500), the chlorides will fall as a white precipitate of silver chloride. If the precipitate is in curdy masses, the chlorides are not diminished; if only a milkiness is produced, they are greatly diminished; and if no cloudiness, they are entirely absent.

Centrifugal Test.—To 10 Cc. of the urine in the graduated tube add a few drops of nitric acid and fill to the 15 Cc. mark with a solution of silver nitrate (1 to 500), mix and then rotate as in the preceding. The amount, if normal, should occupy about 15 per cent.

SULPHATES.—These consist mainly of sodium sulphate, with a little of the potassium salt. They are derived principally from the food and in small quantity from oxidation of albuminoid sulphurized tissues, especially in fevers.

Tests.—(*a*) Barium Test.—First add a few drops of nitric or hydrochloric acid to hold the phosphate in solution; then add barium chloride test-solution U. S. P. (12.2 per cent.) until precipitation is complete. If the precipitate is creamy, the sulphates are increased; if milky, normal, and if only opalescent, diminished.

(*b*) *Centrifugal Test.*—To 10 Cc. of urine add a few drops of nitric acid and fill up to the 15 Cc. mark with the barium chloride test-solution; after rotation the volume of the precipitate is normally one per cent.

Abnormal Urine.

Urine may be abnormal from excess or diminution of the foregoing normal constituents or from the presence of various substances that are never found in healthy urine. Of these, the most important are the proteids, namely, albumin, globulin, albumose and peptone.

ALBUMIN.—By this is generally meant serum albumin which, it not being osmotic, appears in the urine only in pathological conditions and in certain functional disturbances, due to abnormal diffusibility of the blood's albumin or to excessive blood pressure in the kidneys, or oftenest, to lesions in the renal tissues themselves.

Heat Test. — A test-tube is one-third filled with the suspected urine and held in the flame of a spirit-lamp, or over the chimney of an ordinary lamp, until it boils. If an opacity occurs, it must be either *albumin* or *earthy phosphates*. If earthy phosphates, it clears up on addition of nitric acid, but if albumin, it is slightly increased.

Nitric Acid Test.—This consists in under-laying the urine with nitric acid. Take a test-tube one-fourth full, and, holding it aslant, gently pour in an equal volume of the acid, allowing it to trickle down the inside of the tube and pass beneath the urine. Or, the acid may be put in first and the urine added afterward.

Howe's method of applying this test is: Pour about 5 Cc. of the urine into a test-tube and warm it to about 100° F. Through a funnel pipette, reaching to the bottom of the test-tube, add an equal volume of nitric acid. If albumin is present, there will appear at the junction of the two liquids a narrow white band, best seen in a strong light, against a black back-ground.

An opacity at the junction of the two liquids is either *albumin* or *urates*. If urates, it clears up on heating, but if albumin, it is permanent. Either the heat or nitric acid test, singly, is unsatisfactory, but both performed together are conclusive. However, the following sources of error should be borne in mind: (*a*) if the urine is very alkaline and the quantity of albumin small, heat

will cause no opacity ; (*b*) If only a drop or two of nitric acid be added, the acid may hold a small quantity of albumin in solution ; (*c*) urea may be precipitated from a concentrated urine by nitric acid, but heat dissolves it ; (*d*) decomposed urines, containing, as they do, ammonium carbonate, effervesce on addition of an acid ; (*e*) often after taking turpentine, copaiba, etc., nitric acid precipitates the resin in yellowish flakes, re-dissolved on addition of alcohol.

Other Tests.—Among them may be mentioned (*a*) saturated solution of picric acid ; (*b*) potassio-mercuric iodide solution, made as follows : mercuric chloride, 1.35 Gm. ; potassium iodide, 3.32 Gm. ; acetic acid 20 Cc. ; water, 80 Cc. ; the chloride and iodide are dissolved separately in water, and then mixed and the acetic acid added afterward. (*c*) A mixture of equal parts of the saturated solutions of sodium tungstate and of citric acid. (*d*) The potassium ferrocyanide test-solution U. S. P. is mixed with the urine, and a few drops of acetic acid added. (*e*) Acidulated brine test : a saturated solution of common salt to which 5 per cent. of hydrochloric acid is added. Tablets of these chemicals or strips of filter paper steeped in them and dried are sometimes carried for use at the bedside.

Quantitative Estimation.—During the progress of a disease it is often important to estimate the quantity of albumin. The exact method, by drying and weighing the precipitated albumin, is too tedious for the busy practitioner.

The easiest approximative method is to precipitate the albumin by heat, set it aside for twelve hours or until next visit, and then note the proportion of volume occupied by the precipitate, *e. g.*, one-fourth, one-eighth, a trace, etc.

Esbach's Albuminometer (Fig. 56), is a graduated test-tube. Fill it to U with the urine, and to R with the reagent, which is composed of 10 grams of picric acid, 20 grams of citric acid, and water sufficient to make a litre. Gently mix the liquids and set aside for twenty-four hours to allow the precipitate to subside, the depth of which by the scale indicates the number of parts per thousand or grams of albumin in a litre.

Centrifugal Test—Purdy's method is to add to 10 Cc. of the urine in the graduated tube, 3.5 Cc. of the potassium ferrocyanide solution and 1.5 Cc. of acetic acid. After mixing and the usual rotation, all the albumin is precipitated, and each .1 Cc. represents 1 per cent. bulk measure of albumin.

Fig. 56.

GLOBULIN is sometimes associated with albumin in urine, being held in solution by the chlorides. When these become very much diluted, as on allowing a few drops of the urine to fall into a glass of water, the globulin is precipitated as a white cloud, which dissolves on addition of acetic acid.

ALBUMOSE, which is an intermediate product in the digestion of albumin into peptone, occurs in some cases of albuminuria and in osteomalacia. It may be detected by acidifying the urine with acetic acid, adding a saturated solution of common salt, boiling and filtering to remove the albumin and globulin. Albumose will separate as a white cloud as the filtrate cools, dissolving again on heating and reappearing on cooling.

PEPTONE is never found in normal urine, but sometimes occurs with albumin or independent of it. It differs from albumin and albumose in not being coagulated by heat, nitric acid or many other substances that coagulate albumin. It is precipitated, however, by tannin and phospho-tungstic acid.[389]

To detect peptone, the albumin should be first removed, *e. g.*, by acetic acid and potassium ferrocyanide and filtering. It is well also to remove the urinary pigments by acetate of lead and filtering. If phospho-tungstic acid is added to this filtrate a white precipitate is formed if peptone be present.

A simpler but less reliable test is to float the urine over Fehl-

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[389] Phospho-tungstic acid is made by treating a hot solution of sodium tungstate with phosphoric acid till decidedly acid, and then strongly acidifying with acetic acid. Filter after standing several hours.

ing's solution and look for the rose-red zone (biuret reaction) indicative of peptone.

Clinically peptonuria indicates the disintegration and absorption of pus corpuscles somewhere in the body and so is a valuable symptom in the differentiation between purulent and nonpurulent diseases, *e. g.*, between hydro- and pyothorax or between tubercular and cerebro-spinal meningitis, the latter being purulent and attended with peptonuria.

MUCIN.—In moderate quantity, mucin is a normal constituent of urine; but may be abnormally increased in irritation of the genito-urinary mucous membrane. It is closely related chemically to albumin; but not coagulated by heat or strong mineral acids; but is precipitated by alcohol and organic acids. Mucin is one of the most frequent sources of error in searching for small quantities of albumin. It is easily detected by its forming, on standing, a sediment slightly opalescent from entangled epithelia and floating near the bottom of the urine. It may be detected also by floating the urine over acetic acid and noting the slight coagulation in the zone of contact.

SUGAR (*Glucose*). It has been proved (Dr. Pavy, 1879) that healthy urine may contain traces of glucose; but that quantities, appreciable by the ordinary tests and of chemical significance, constitute glycosuria, which is the most prominent and sometimes the only symptom of diabetes mellitus—a serious pathological condition, associated with disturbance of the glycogenic function of the liver.

A temporary glycosuria may occur after the administration of anæsthetics and other drugs, and in certain nerve and brain lesions, especially those involving the floor of the fourth ventricle. High specific gravity in a urine, pale and copious, suggests sugar. Before testing, albumin, if present, should be removed by boiling and filtration.

Fermentation Test.—Two vials, one for comparison, the other for fermentation, are partly filled with the urine. Into one is put a bit of baker's yeast about the size of a pea. Both vials are

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loosely plugged with some pervious material, as cotton, and set aside where they will keep warm (60° or 70° F.) until next day or next visit. If sugar is present, fermentation will occur in the vial treated with yeast, and CO_2 bubbles up and passes off through the cotton plug; and on taking the specific gravity of each, there will be a difference, owing to the loss of sugar in the vial fermented.

Alkali Test.—Boil the urine with liquor potassæ or sodæ, and if glucose is present, it will be oxidized and form a molasses-like coloration, the depth of which indicates the quantity of sugar present. On adding nitric acid a molasses-like odor is developed and the coloration is discharged.

Alkali-Copper Test.—This depends on the power glucose has of reducing the cupric to the cuprous oxide. There are several methods of performing this test :—

(1) *Trommer's.* A drop or two of a weak (about 1 to 30) solution of cupric sulphate is added to an inch of urine in a test-tube, and then an equal bulk of liquor potassæ or of liquor sodæ. Immediately there falls in addition to the earthy phosphates, a bluish precipitate. If sugar is present, this precipitate dissolves on agitation, forming a blue solution, which, on boiling, deposits a yellow, orange or red precipitate of cuprous oxide. (See page 120.)

(2) *Fehling's.* This differs from Trommer's in that tartaric acid or some tartrate is added to dissolve the blue precipitate. Furthermore, the ingredients are in definite proportion, so as to make the solution available for quantitative analysis. Below are given the two formulæ in general use, one in the French and the other in the English measures :—

	Fehling's Solution.	Pavy's Solution.
Cupric sulphate	34.64 grams.	320 grains.
Potassium tartrate	173.20 grams.	640 grains.
Caustic potash	80.00 grams.	1280 grains.
Water, enough to make	1 liter.	20 ounces.

(3) *Haines'* differs from Fehling's in that glycerine is used

instead of the tartrate, and that it does not spoil. Dissolve 34.64 gm. of cupric sulphate in 200 Cc. of water and add 175 Cc. of glycerine. Dissolve 130 gm. of caustic potash in 500 Cc. of water. Mix the two solutions and dilute to one liter.

Alkali-Bismuth Test.—(1) To some urine in a test tube add a pinch of bismuth subnitrate and then an equal volume of liquor potassæ. Boil about two minutes. If sugar be present, the bismuth will be reduced and deposited as a black metallic deposit on the sides and bottom of the tube. (2) A bismuth test solution, corresponding to Fehling's, is made by warming a scruple each of bismuth subnitrate and tartaric acid in two ounces of water, and adding liquor potassæ until a clear solution is obtained. This boiled with a urine containing glucose gives the black bismuth precipitate.

The elements of the foregoing tests put up in pellets or tablets, while more convenient, are less reliable and spoil sooner than the solutions.

Picric Acid Test.—This is an extremely delicate test for glucose, and depends on the fact that glucose in the presence of a strong alkali will reduce yellow picric acid solution into blood red picramic acid. It has the practical advantage of being as good a test for albumin. To the suspected urine add an equal volume of a saturated solution of picric acid. A cloudy precipitate indicates albumin. Next add a few drops of liquor potassæ and warm gently. A *deep red* color indicates sugar, though a lighter coloration may occur in urine free from glucose.

Indigo-Carmine Test.—To the urine add a solution of indigo-carmine rendered alkaline by sodium carbonate. Boil, and if sugar is present the blue mixture changes to violet-red and yellow. On agitation, oxygen is absorbed from the air, and the above changes of color are reversed.

Phenyl-hydrazin Test.—A very certain though somewhat tedious test is made by mixing in a dish 25 Cc. of suspected urine, 1 gm. of phenyl-hydrazine hydrochlorate, .75 gm. of sodium acetate and, unless the urine is already sufficiently diluted, 10 Cc. of water

Heat the dish on a water-bath for an hour ; when removed and allowed to cool there will appear, if sugar is present, a yellowish deposit of phenyl-glucosazon, which under the lens is seen to consist of bundles of needle-like crystals radiating from a common center.

Quantitative.—(1) *Fermentation.* Each degree of specific gravity lost in fermenting represents one grain of sugar to the ounce of the twenty-four hours' urine.

(2) *Fehling's. Two hundred minims of the solution is decolorized by one grain of sugar.* Two hundred minims (grains) of the test solution are measured off into a small flask, diluted with twice its bulk of water, and gently boiled (Fig. 57). A gradu-

Fig. 57.
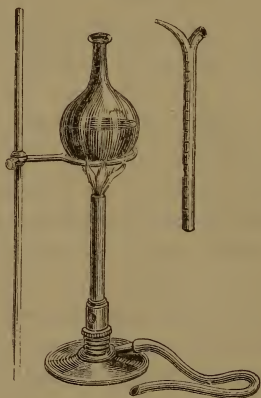
ated burette (also shown in figure) is then filled to zero with the urine. To the boiling test solution, the urine is added drop by drop till the blue color is discharged. By the graduations on the burette the quantity of urine added is easily read. As that represents one grain of sugar, the amount of sugar in the entire urine is easily calculated.

3. *Alkali Test.* A light yellow indicates one per cent. ; dark amber, two per cent. ; sherry wine, three per cent. ; dark Jamaica rum, five per cent. ; and dark, almost opaque, ten per cent.

ACETONE is found in the urine in cases where there is great decomposition of tissue albumin, as in high fevers, diabetes mellitus, carcinoma (in the stages of breaking down), inanition, mania and intestinal auto-intoxication. It is said to be a constituent of normal urine, but only as a trace. It often precedes a more dangerous symptom, namely, diaceturia. It is acetone that gives diabetic urine its fruit-like odor.

Lieben's Test.—Add to urine a solution of sodium hydrate in excess and then a few drops of a solution of iodine and potassium iodide. If acetone is present there occurs a precipitate of iodoform with its characteristic odor.

DIACETIC ACID.—Since it never occurs in normal urine, its pressure must always be regarded as a dangerous symptom. It has been observed that it is always of more significance when found in adults than in children. In diabetes millitus it is preceded by acetonuria and is generally followed by coma (diacetic coma usually known as diabetic coma) and by death.

In children there sometimes occurs an idiopathic diaceturia or an auto-intoxication, attended by malaise, thickly coated tongue, generally constipation, slight or no fever, vomiting, dyspnœa, jactitation, coma and death. In other cases, however, the symptoms last two or three days and then recovery takes place. Diaceturia may also occur during the high temperature of some of the acute diseases, as typhoid, pneumonia, miliary tubercolosis and others.

Test.—Solution of ferric chloride with urine containing diacetic acid gives a red color, but caution must be used since certain drugs, as the cinchona salts, acetic, formic, carbolic and salicylic acids, may cause the same reaction in the urine.

CALCIUM OXALATE occurs in extremely small amounts in normal urine, but more abundantly in the so-called oxalic diathesis and in certain forms of dyspepsia, or after eating rhubarb or other things containing it. If persistently present, it may form a (mulberry) calculus. It occurs in both acid and alkaline urine, and always as a light, delicate precipitate, which under high powers is

seen to consist of small, brilliant, octahedral crystals, but some-
times dumb-bells. (Fig. 54). In certain aspects the smaller
octahedra appear as squares crossed by two bright diagonal lines.

CALCIUM CARBONATE is a very rare deposit in human urine,
but abundant in that of cattle. It occurs in small spherules
(Fig. 58) sometimes coalescing ; acetic acid dissolves it with
effervescence.

HIPPURIC ACID (*Horse-uric Acid*) largely replaces uric acid in
the urine of herbivorous animals, and, to some extent, in that of
man, especially after a vegetable diet. It occurs in pointed, four-
sided prisms and acicular crystals, insoluble in acetic acid but
soluble in alcohol. (Fig. 58.)

FIG. 58.
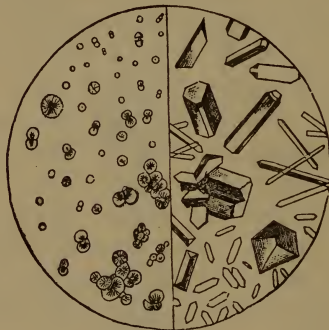
Carbonate of Calcium.   Hippuric Acid.

BILE.—In certain conditions, especially those attended with
jaundice, the urine contains bile coloring matters and usually
smaller quantities of the bile-acids. Such urine is yellowish-
brown, forms a yellow froth on agitation, and white paper or cloth
wet with it is stained yellow.

Tests for Bile Coloring Matters.[390]—Underlay the urine with

[390] Bilirubin oxidizes so easily that icteric urine often gives only the green
coloration, or, if kept long, fails to respond at all.   Hence, if fresh icteric urine
cannot be obtained and bile urine must be prepared for demonstration, fresh
bile from a recently killed animal, and not the inspissated, must be used.

(*a*) yellow nitric acid (that containing nitrous acid) ;[391] or (*b*) a mixture of nitric and sulphuric acids ; or (*c*) tincture of iodine. If bile is present, there is observed at the junction of the liquids a play of colors in which *green* is prominent and characteristic.   If the acid and urine are placed adjacen on a white plate, the colors are more plainly visible.   Another method of performing these tests is to shake the urine with chloroform, which dissolves out the bile coloring matter and shows more slowly and plainly the play of colors produced with the foregoing reagents.

Tests for Bile Acids.—Add a few grains of cane sugar or glucose

FIG. 59.
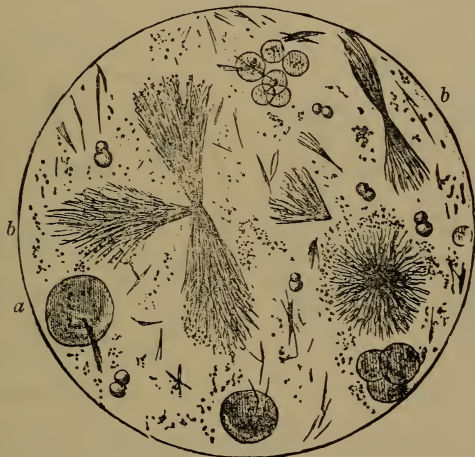
Leucin Spherules and Tyrosin Needles.

to the urine and underlay it with sulphuric acid.   At the junction of the liquids a reddish-purple color appears.   As other substances than bile-acids may produce this reaction, we must, in cases of doubt, before applying the test, evaporate the urine to dryness,

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[391] If a yellow (decomposed) nitric acid is not at hand, an efficient one may be made by adding a bit of zinc to some pure, fresh nitric acid.

dissolve in alcohol, filter, again evaporate to dryness, and redissolve in water.

LEUCIN AND TYROSIN occur only in bile urine, for they attend destructive liver disease, especially acute, yellow atrophy and phosphorus-poisoning. They form yellowish crystalline deposits (Fig. 59)—leucin as spherules, with concentric striæ, and tyrosin as sheaf-like bundles of fine needles.

CYSTIN is a rare urinary sediment, a yellowish deposit of hexagonal plates (Fig. 60), not dissolved by heat or acetic acid, but readily by ammonia. It is a highly sulphurized body whose formation in the system is obscure. It sometimes forms calculi.

BLOOD.—Hæmaturia (blood in urine) may occur as the result

FIG. 60.   FIG. 61.
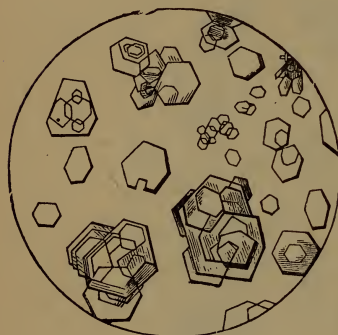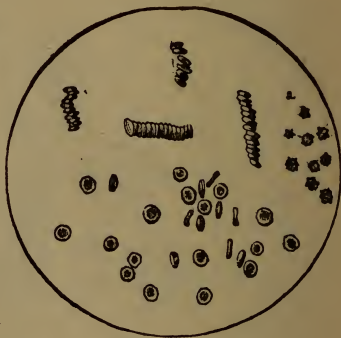
Cystin.   Blood Corpuscles.

of (*a*) some disease or injury of the genito-urinary tract, as acute nephritis, calculus, parasites, cancer, wounds, etc.; (*b*) a depraved condition of the blood, as in scurvy, purpura and certain infectious diseases; (*c*) of a disturbance of the renal circulation, as in mental emotions, malarial paroxysms and cardiac obstructions.

Bloody urine, if acid, is of a smoky hue, or even of a dark reddish brown; if alkaline, of a brighter red. If coming from the kidneys the blood corpuscles are diffused through the urine; but if

from the bladder or urethra, they may be in rouleaux, or even clots. Owing to the biconcavity of the corpuscles, their centers and peripheries alternate in brightness and shadow, as the object-glass is made to approach or recede. Their color and smaller size also serve to distinguish them them from pus corpuscles. In doubtful cases a minute drop of blood, taken from the finger with a needle, may be used for comparison. After urine containing blood has stood for some time, the corpuscles lose their regular outline and become shrivelled and angular. (See *a* in figure.) If the corpuscles are disintegrated and dissolved, we must *test* for *blood coloring matters*.

The spectroscope offers the best means for their detection, but as physicians are seldom provided with that instrument, the following is the usual *test :* Place the urine in a test-tube and shake up with equal volumes of tincture of guaiacum and ozonized ether or old oil of turpentine. If blood coloring matters are present, the precipitated resin is *blue*, instead of a dirty greenish-yellow.

Pus occurs in the urine whenever there is suppurative inflammation in any part of the genito-urinary tract ; such urine is always more or less turbid and albuminous. This turbidity may be distinguished from that due to urates or earthy phosphates, since heat, that would clear up the urates, and acids the phosphates, only serve to increase the turbidity of purulent urine by coagulating its albumin. This turbidity is due to pus corpuscles, rounded, colorless, very granular cells, a little larger than red blood corpuscles and practically identical with mucous corpuscles and leucocytes, except that pus corpuscles oftener have more than one nucleus (Fig. 63.)

If the urine is greatly diluted, or, better still, treated with acetic acid, the cells swell up, lose their granular appearance and become transparent (Fig. 63, *a*). Pus may be distinguished from mucus by : (*a*) it is always attended with albumin ; (*b*) treated with an alkali it forms a gelatinous mass (Donné's test ; (*c*) it effervesces on addition of hydrogen peroxide.

Pus is most conveniently estimated by sedimentation, especially with the centrifuge and noting its percentage of volume.

FAT in such quantities as to float on the urine generally comes from the introduction of a catheter, or from foreign admixture. Fatty degeneration of kidneys, or leakage of a lymph vessel, or the opening of an abscess into the urinary tract may cause Lipuria (fat in the urine). It occurs as minute, highly refracting globules of various sizes (see *a* in figure 62) ; but sometimes, es-

FIG. 62.   FIG. 63.
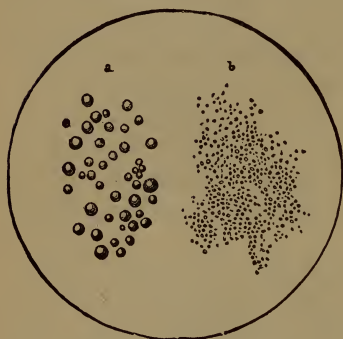
Fat Globules.   Pus Corpuscles.

pecially in chylous urine, in more intimate emulsion (as at *b*,) the globules appearing under the microscope as mere specks. Fat may be recognized by its dissolving on addition of ether.

EPITHELIA in the urine may come from any part of the genito-urinary tract. The accompanying cut shows the typical forms of cells coming from various situations. It is generally impossible to locate the origin of an epithelial cell beyond the vagina and bladder, for their distinctive differences, but slight at best, are rendered still fainter by maceration in the urine. *Renal* epithelium comes from the uriniferous tubules, and are rounded and granular, and, unlike pus cells, they show their nuclei without acetic acid. They are usually associated with albumin and tube casts (Fig. 65), and therefore point to kidney disease. Though we cannot know

from what site the epithelia come, we can judge fairly well the condition of the mucous membrane by the number and character of the cells thrown off. For in acute diffuse inflammation of the kidneys, they appear in great numbers, often adhering to renal casts, or to each other. In the more chronic lesions, these cells

FIG. 64.

(*a*) Epithelium from the human urethra; (*b*) vagina; (*c*) prostate; (*d*) Cowper's glands; (*e*) Littre's glands; (*f*) female urethra; (*g*) bladder.

are much disintegrated and more or less filled with oil globules.

TUBE CASTS.—In hemorrhage from or inflammation of the kidney the urine usually contains microscopic casts, or moulds of the uriniferous tubules, formed by exudation, into the tubules, of coagulable material, which afterwards contracts, becomes loose, and is washed out with the urine. As these casts imbed and bring away epithelial cells, granular matter, fat globules, blood disks, etc., they are a valuable index to the condition of the tubules. They are described by clinicians as (1) *Epithelial* casts (see upper portion of

Figure 65), are those bearing renal epithelium. They indicate desquamative nephritis. (2) *Hyaline* casts (shown in left-hand part of figure) are transparent and comparatively free from entangled material. They come from tubules whose epithelium is sound and adherent, or from those bereft of epithelium. In the latter case they are more solid in appearance (*waxy casts*) and indicate serious nephritis. (3) *Granular* casts are opaque from presence of granular *debris*. (4) *Fatty* casts (see largest cast in figure) are such as carry oil globules, either free or contained in

FIG. 65.

Epithelial Cells and Tube Casts.

epithelial cells. They are proof of fatty degeneration of the kiddeys. (5) *Blood* casts contain blood corpuscles, and show that the hæmaturia is of renal origin. (6) *Bacterial* casts are composed of micrococci and show the nephritis to be of septic character.

Casts, especially in a urine of high specific gravity, subside so very slowly that hours are required for them all to reach the bottom, and the urine may, in the meantime, especially in summer, undergo such marked changes as to make them unrecognizable ; or they may become obscured with clouds of micro-organisms or other newly formed precipitates. Much of this difficulty is

now avoided by the use of the centrifuge, which does, and does better, in a few minutes what formerly required as many hours.

The sediment should be removed with a pipette, placed in a shallow cell upon a glass slide, and examined under a cover-glass; the clear hyaline casts are especially difficult to find and should be looked for under oblique illumination. Some advise the use of staining agents to better differentiate these from the clear urine.

SPERMATOZOA occur in urine as a result of spermatorrhoea, nocturnal emissions, or coitus. They are liable to escape obser-

FIG. 66.

Spermatozoa.

vation, for they subside slowly, and are very small and transparent. Under a high power they are seen to consist of a small oval cell with a tail-like prolongation. Their tadpole-like appearance is shown in Figure 66. They are motionless in urine, and remain for days unaltered.

MICRO-ORGANISMS.—The urine, though generally sterile when in the bladder. becomes, as soon as voided, a ready medium for the growth of the lower forms of life, the germs of which get in from the air or unclean vessels. Among others we may mention: (1) yeast fungus which is usually seen during sporule stage as transparent oval cells, sometimes arranging themsselve in

branches. It grows only in saccharine urine, though spores closely resembling it are seen in acid urine containing neither sugar nor albumin. (2) *Sarcina* is a fungus seldom found in urine, but more frequently in matters vomited during certain diseases of the stomach. The cells are arranged in cubes, resem-

FIG. 67.

(*a*) Micrococci in short chains and groups; (*b*) sarcinæ; (*c*) fungi from acid fermentation; (*d*) yeast cells from diabetic urine; (*e*) mycelium of a fungus.

bling bales bound with cross-bands. The sarcinæ shown at *b* in Fig. 67 are from the urine, smaller than those from vomited matters.

3. *Bacteria* (*little rods*). This is the general term given to the minute, moving organisms invariably present in putrefying animal and vegetable matter. They consist of simple cells filled with a colorless fluid and presenting several varieties of form: (*a*) micrococci appearing as trembling points, distinguished from other particles by their progressive motion; (*b*) *rods* about the

length of the diameter of blood disks, sometimes at rest, but usually vibrating across the field, (*c*) *Vibriones*, consisting of several rods joined together and moving with greater rapidity; and (*d*) *Zooglæ*, aggregations of bacteria held together by gelatinous material and resembling masses of amorphous urates or phosphates. These various forms are shown in Figures 45 and 46. Bacteria not only cause decomposition outside, but may set it up in urine while yet within the bladder, provided they are introduced from without. This may be done by dirty catheters and sounds, or they may work their way down the urethra in the pus of a gleet. The ammoniacal fermentation thus set up soon induces cystitis. The characteristic microbes of various diseases have been observed. The "bacillus tuberculosis" is most frequently found and easily demonstrated by staining the sediment in the ordinary way and is of great clinical importance, as it is certain evidence of tubercular ulceration of the bladder or other portions of the urinary tract.

EXTRANEOUS BODIES, such as hair, wool, or fragments of feathers, are often found in urinary deposits, and ludicrous mistakes have been made by observers not on their guard for such casual admixtures.

URINARY CALCULI.—Urinary calculi (*calculus*, a pebble) are composed of urinary sediments which have gathered around some nucleus (usually calcium oxalate or uric acid crystals or some foreign body) within the bladder, and being slowly deposited, particle upon particle, and layer upon layer, the concretion becomes as hard as stone. Calculi are not always composed of the same material throughout, but often consist of successive layers of different sediments deposited during varying conditions of the urine.

The qualitative analysis of calculi is easy. Saw the stone through the middle, and see whether it is composed of the same material throughout or of successive layers of different sediments. If the former, take the sawdust; if the latter, chip off a specimen from a single layer. This should be pulverized *very fine* (for it is dissolved much less readily than fresh sediments),

and then tested by means of heat, acetic and hydrochloric acids ; for in the great majority of cases it will be found to consist of urates, phosphates, calcium oxalate or uric acid. Place the powder in a test-tube, and add 5 Cc., of water ; boil, and if it dissolves it is *urates*. If not, add acetic acid, and warm again ; if it dissolves it is *phosphates*. If not, boil with hydrochloric acid ; if it dissolves, it is *calcium oxalate*. If not, it is *uric acid*, which may be confirmed by the murexid test.

The following method is easier and surer :

I. Heat to redness on a piece of platinum foil. If no residue, see II ; if a residue, see III.

II. To a fresh portion apply the murexid test. If it responds it is *ammonium* urate, or *uric acid ;* if it does not respond, it is *cystin* or *xanthin*, see IV.

III. To the residue, when cool, add hydrochloric acid. If it effervesces it is an *oxalate* or *urate*, which may be determined by the murexid test ; if it does not effervesce, it is a *phosphate*.

IV. Dissolve some of the powder in nitric acid. If the solution is yellow it is *xanthin ;* if dark brown it is *cystin*.

MILK.

Female mammalia all possess certain glands (mammary) that secrete, for the nourishment of their young, an opaque white fluid called milk.[390] It possesses a peculiar odor, often quite characteristic of the animal from which it is derived. Its opacity is due to minute globules of fat, or butter, each more or less surrounded by an albuminoid envelope and suspended in the fluid and presenting under the microscope[391] the appearance shown in figure 68.

In the colostrum, which is the name given to the milk secreted

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[390] Procure a liberal supply of ordinary milk at least three hours beforehand and let it stand. Siphon off the lower two-thirds and label it " skim milk " and the residue " cream." Procure another supply of fresh milk just before the exercise opens.

[391] Examine a drop of milk with a microscope.

during the first few days after parturition, these albuminoid en-velopes are seen to be large epithelial cells (colostrum cells) undergoing fatty degeneration and completely enclosing the fat globules.

Fig. 68.

Mllk.

Colostrum.

(Holland.)
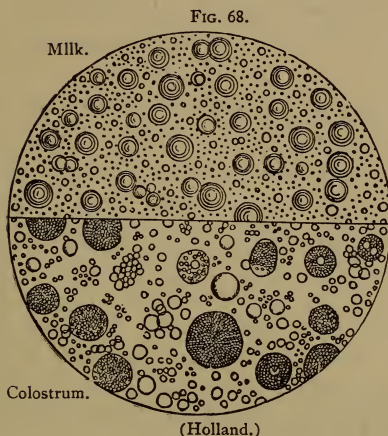
The reaction [392] of cow's milk is often acid, but that of woman's milk should be feebly alkaline. Milk, when exposed to the air, soon undergoes the lactic acid fermentation (sours), thus,
$$C_{12}H_{22}O_{11} + H_2O = 4H_2C_3H_4O_3.$$

The specific gravity [393] varies from 1029 to 1035. The quan-tity of milk an animal will secrete depends upon the health, food, drink, etc. A woman should secrete about one liter, while a good cow should produce about ten times as much.

Composition.—The milk of all animals consists of water hold-ing in solution casein, albumin, sugar and mineral salts, and sus-pending globules of fat. It is the only perfect food, especially for the young.

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[392] Test the reaction with red and blue litmus papers.

[393] The specific gravity may be measured with the ordinary urinometer dis-tributed to the students, but the teacher should exhibit a lactometer, Fig. 69.

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The composition of milk varies with the species and breed of the animal and with the individual. Even in the same individual it varies with the health, food, manner of living, period of lactation and many other circumstances.

Woman's and cow's milk are the most important. The following table (König) shows their comparative composition:

ANALYSIS OF HUMAN MILK AND COW'S MILK (König).

	Woman's Milk.			Cow's Milk.		
	MEAN.	MINIMUM.	MAXIMUM.	MEAN.	MINIMUM.	MAXIMUM
Water	87.09	83.69	90.90	87.41	80.32	91.50
Total solids	12.91	9.10	16.31	11.59	8.50	19.68
Fat	3.90	1.71	7.60	3.66	1.15	7.09
Milk sugar	6.04	4.11	7.80	4.92	3.20	5.67
Casein	0.63	0.18	1.90	3.01	1.17	7.40
Albumin	1.31	0.39	2.35	0.75	0.21	5.04
Albuminoids	1.94	0.57	4.25	3.76	1.38	12.44
Ash	0.49	0.14	?	0.70	0.50	0.78

PROTEIDS.—Of these by far the most important and interesting is *casein*, though there is a small amount of albumin and globulin; but these latter are so similar to serum albumin and serum globulin as to need no special description.

Casein.—It is claimed that the casein is not in actual solution; but if not, it is suspended in such a loose, thin, liquid condition that it flows and drips as a solution. The casein seems to be held in solution by calcium phosphate, and some call it caseinogin, reserving the name casein for the coagulated substance. It does not coagulate on boiling,[394] the scum forming on the surface being coagulated albumin. It dissolves readily in alkalies and is often compared with alkali-albumin; is easily coagulated by acids,[395] and most easily by the stomach ferment, known to cheese-makers as

[394] Boil a sample of skim milk and note that the casein is not coagulated, but a scum of albumin forms.

[395] To another sample add a few drops of acetic acid and note that the casein is coagulated, but that it dissolves on addition of an alkali; to be reprecipitated on addition of more acid, and so on.

rennet,[396] one part of which will coagulate several hundred thousand parts of casein.

In mother's milk the coagulum is flocculent and easier of digestion; while in cows' milk it is in firmer clots and more indigestible, but it may be made somewhat easier of digestion if the milk is previously boiled or alkalinized or diluted with some gelatinous substance.

The clear fluid that separates from the coagula is known as *whey*,[397] and is of considerable nutritive value, since it contains all the constituents of the milk except the casein and entangled fat globules.[397]

FAT.—The fat globules of milk contain also traces of cholesterine, of lecithin and of a yellow coloring matter closely allied to the lutein of yolk of egg. The albuminoid envelopes previously mentioned are broken in the process of churning, and the fat globules coalesce in lumps, forming *butter*.

The butter may be also extracted with ether,[399] and without churning, provided the milk be previously treated with alkali or acetic acid to dissolve away the albuminoid envelopes.

MILK SUGAR.—(Lactose.)[400]—This has already been mentioned with the other carbohydrates; it differs from them, however, in fermenting into lactic acid, a reaction that occurs spontaneously whenever milk is exposed to contamination from the air and allowed to stand at ordinary temperatures. The lactic acid thus

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[396] Warm some milk in a beaker to blood-heat and add a few drops of extract of rennet or essence of pepsin, and note that in a few moments the milk is coagulated and that a clear liquid separates from the curd.

[397] Remove the fluid by filtration and label " whey."

[398] Take successive portions of the whey and test with the xanthoproteic reaction, Millon's reagent, etc.

[399] Take some milk in a test-tube, add a little alcohol and caustic potash, and shake with ether. Pour off the ether into a dish and evaporate it; butter is left behind. Notice also the characteristic smell of butyric ether, especially if a few drops of H_2SO_4 be added.

[400] Test the whey for lactose by the alkali-copper and other tests described elsewhere. The teacher should show some practical work with the creamometer and lactoscope.

produced quickly coagulates the casein and the milk "sours" and becomes "clabber."

This fermentation is due normally to the implantation of the bacillus acidi lactis, which rapidly proliferates unless the milk is kept very cold or treated with antizymotics. Occasionally milk is contaminated with other bacteria, especially the bacillus cyanogenus, and, turning blue, slimy and bitter, developes tyrotoxicon, the poisonous alkaloid which has been responsible for so many deaths.

To prevent these fermentations various methods have been used; that of refrigeration has been employed since time immemorial; and milk kept cold will remain sweet for days, but in spite of the greatest care the ferment will gain access and remain to set up fermentation in the child's stomach and disturb its digestion. To prevent this, the milk may be boiled ("sterilized milk"),[401] but the high heat coagulates the albumin and globulin, and impairs the casein; and children fed on this milk do not thrive. By heating the milk to not over $75°$ C., or $167°$ F. ("pasteurization") these changes in the proteids do not occur, though many of the organisms are destroyed, and others so weakened that the milk does not readily spoil, and is much less likely to disagree with the infant.

SALTS.—These consist mainly of phosphates of calcium, magnesium, sodium and potassium, with the chlorides of sodium and potassium and a trace of iron.

ADULTERATION.—Of the many ways of adulterating milk, the most common methods are, (a) *chemicals*, employed mainly as preservatives, such as salicylic acid, sodium carbonate or borate; the two latter neutralizing the lactic acid and delaying the coagulation; (b) *skimming* off the cream, or fatty layer, that gathers at the top of milk when allowed to stand. This not only deprives

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[401] Let the student boil some milk in a test-tube, then close it with a plug of dry absorbent cotton and set it aside to note that it remains sweet and unaltered for days and weeks. The teacher should also show some standard sterilizer, as Arnold's.

the milk of a valuable constituent, but, unless the new and rapid centrifugal process is used, delays its delivery for at least half a day, thus increasing the danger of contamination and decomposition ; (c) *dilution*,[402] which is a very common practice, but less dangerous to health, unless the water is contaminated with typhoid or other infectious germs.

MILK TESTING.—The specific gravity of good milk should not be below 1029 unless the milk is unusually rich in fats, which being lighter than the rest of the milk, lowers the specific gravity ; and if it rises above 1035 the milk has probably been skimmed.

FIG. 69.   FIG. 70.
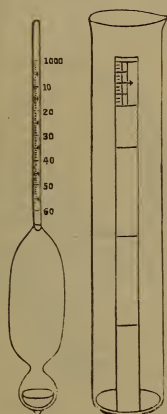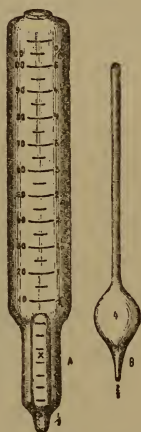
Hydro-   Creamo-   Feser's Lactoscope.
meter.   meter.   (Queen.)
      (Starr.)

Skim milk, however, may be so diluted as to bring its specific gravity within the ordinary limits, but an experienced eye can readily see that instead of being white, the milk assumes a bluish tinge, or in other words loses the natural opacity imparted by the suspended oil globules.   So the measurements of the specific

[402] Let the student dilute a specimen of milk in a test-tube or beaker, and note the bluish tint produced.

gravity are not conclusive unless the opacity be also observed : This is easily done by the lactoscope (Fig. 70),[403] which consists of a cylinder of clear glass (A), containing at the lower part a smaller cylinder of white glass (resembling that shown at x, fig. 70), upon which are a few black lines. In testing, 4 Cc. of the milk are introduced from the graduated pipette (B), and the black lines are entirely concealed by the opaque milk ; pure water is then gradually added with shaking until the milk is clear enough for the black lines to be visible. The level of the diluted milk in the cylinder is then read off in the graduations as percentage of fat in the original sample. This method is quick, accurate and reliable, unless the milk be adulterated with some suspended white powder, as chalk or starch, in which case the microscope will disclose its nature.

A simple but rough estimate of the cream may be made by allowing the milk to stand over night in a graduated cylinder such as the *creamometer* shown in Fig. 69.[404]

The *centrifuge* (Figs. 71 and 72) with milk-tubes and a volume-pipette (Fig. 73) affords a very quick and fairly accurate method of estimating the quantity of fats. Add to each milk-tube 5 Cc. of the milk, 1 Cc. of the HCl solution (hydrochloric acid, 50 volumes ; methyl alcohol, 13 volumes ; fusel oil, 37 volumes) ; shake well and add strong sulphuric acid (sp. gr. 1.83) drop by drop with constant shaking until tube is filled to the zero mark. Rotate for two minutes and read the percentage of fats directly from the scale. As the graduations extend only to 5 per cent., a milk richer than this must be diluted, and the reading multiplied according to the dilution.

The above methods of estimating the amount of fat, although very useful, are not sufficiently reliable and accurate for official inspection. Milk may vary in consistence as well as in composition, so that one specimen may furnish more cream than another

---

[403] The teacher should show actual work with a creamometer and lactoscope.

[404] Let each student chew a piece of paraffine and collect the saliva in a beaker.

containing twice as much fat. For accurate work, the *Werner-Schmidt process* is very convenient, viz., take 10 Cc. of the milk and 10 Cc. of strong HCl; pour into a long test-tube of about 50 Cc. capacity. Bring the mixture to a boil; when cool add 10 Cc. of ether and shake well; as soon as the ether has all risen to

Fig. 71. Fig. 72. Fig. 74.

Fig. 73.
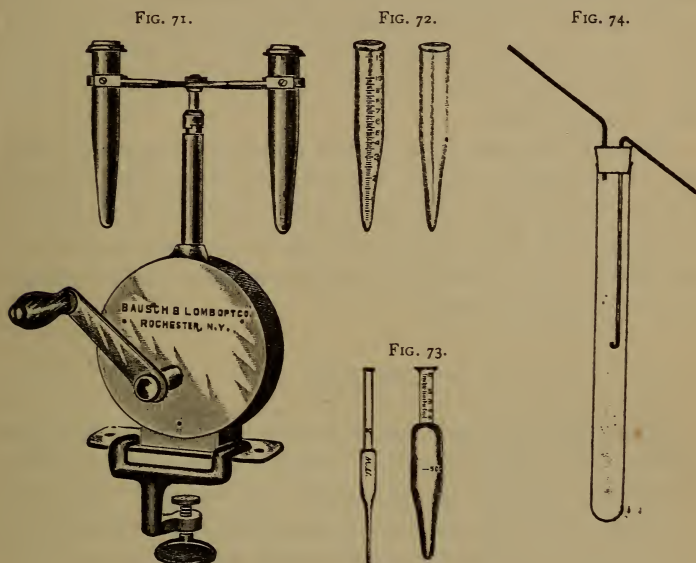
the top, remove the cork and insert the perforated cork and tube, as shown in figure 74.

By sliding the exit tube down until it opens just above the line of separation, the ether solution of the fat can be blown into a previously weighed beaker; another portion of ether is added to the test-tube, shaken and blown out as before, repeating the process two or three times. The ethereal solution is now evaporated over a water-bath and the beaker weighed. The amount of fat thus obtained represents that contained in 10 Cc. of milk and shows the percentage.

Clinical Test of breast milk is generally neglected by the practitioner, though it has been long recognized that the milk of different women, or even of the same woman under different conditions, health, diet, exercise, etc., often disagrees with the nursling. Dr. Emmet Holt, of New York, who has made extensive studies along this line, has shown that these clinical variations are attended by, and possibly caused by, variations of specific gravity, reaction and percentage composition. The specific gravity of human milk should range from 1028 to 1033 and the quantity cream from 3 to 4 per cent.

Kumyss is the name given to milk fermented under the influence of a peculiar ferment, originally imported from Southern Russia. The lactose is made to undergo the vinous fermentation, producing alcohol and carbon dioxide in the presence of the yeast plant. It is a valuable stimulant and food stuff in malnutrition and wasting diseases.

SALIVA.

Human saliva is a viscid, tasteless, opalescent, alkaline fluid, the product of the salivary glands.[404] Its active principle is *ptyaline*, the function of which is to convert starches into glucose.[405] It acts best in neutral reaction ; strong alkalies or acids retard or even destroy it. Saliva also contains potassium sulpho-cyanate,[406] the function of which is unknown.

---

[405] Put some saliva with a few drops of starch solution in four test-tubes and label *a, b, c* and *d*. To *a* add two drops of HCl; to *b* five drops of liquor potassæ; boil *c*. Set all four test-tubes in a beaker of water; warm no hotter than the hand can easily bear. After ten minutes remove and test each tube for starch and sugar. It will be found that only in *d* has the ptyaline converted the starch into glucose, for acids and alkalies restrain the ptyaline, and boiling destroys it.

[406] To some saliva in a test-tube add a drop of ferric chloride, a blood-red color indicates potassium sulpho-cyanate.

GASTRIC JUICE.

Gastric juice is a thin, yellowish, sour liquid, of specific gravity seldom over 1010, and of somewhat variable composition. It may be obtained fairly pure from man and other animals, through gastric fistulæ or more usually the stomach-pump, or stomach-tube. It is secreted and reabsorbed in surprising quantity, a man producing from fifteen to thirty pounds a day.

Its composition may be stated as

Water	99.44
Pepsin and other organic matter	.32
Hydrochloric acid	.25
Sodium chloride....................................	.14
Potassium chloride.................................	.05
Calcium chloride	.006
Calcium and magnesium phosphates..................	.015
	100.221

Pepsin is a ferment that in connection with acids has the property of converting, by a process of hydration, the albuminoids into albumoses and finally into peptones, making them osmotic and capable of being taken up by the vessels of the stomach. It digests only nitrogenous food, the oils, fats, starches and sugars being unaffected by it. The process is retarded by too little or too much acid and by alcohol. The pepsin does not seem to be destroyed in the process, but continues to act almost indefinitely, digesting large quantities of the proteids. Its acidity is due mainly to *hydrochloric* and certain *organic acids*, as lactic, butyric and acetic, but these latter are incidental and mainly the result of fermentative action.

Clinical examination of gastric juice is becoming each year a more and more important means of diagnosis in stomach diseases. The usual method is, first to thoroughly wash out the stomach with warm water and, some hours afterward, administer a test-meal. This is usually a light breakfast consisting of an ounce and a-half of dry roll and eight ounces of water, or weak tea

without milk or sugar. To insure thorough mastication and salivation twenty minutes should be occupied in consuming the meal, and the water or tea should be drunk last. One hour afterwards, the secretion of HCl (one of the two chief agents in proteid digestion) being at its maximum, the remains of the liquefied food are drawn off and examined, first ocularly to determine the degree of disintegration and solution. Normally, all of the nine and one-half ounces of the test-breakfast, with the exception of one and one-third ounces, should be absorbed, or passed into the small intestines at the end of an hour. If a larger amount is found it indicates slow absorption; if a smaller, more rapid absorption than normal. The stomach contents, light yellow in color, are then filtered, and the filtrate examined according to the following scheme:

Filtrate of stomach contents after a test-breakfast. Color clear yellow.

Qualitative Tests.—

    (1) *Litmus test*—reaction acid (red).

    (2) *Free acid*, Congo-red test—very delicate, reaction blue.

    (3) *Free HCl*, Gunzburg's test, Boas's test—reaction carmine red.

    (4) *Lactic acid*, Uffelman's test—reaction greenish yellow.

    (5) *Rennet ferment*, Milk test—coagulation.

    (6) *Butyric acid*—decolorizes Uffelman's reagent.

    (7) *Acetic acid*, odor test.

Quantitative Tests.—

    (8) *Estimation of total acidity* by saturation.

    (9) *Estimation of free HCl* by Leo's method.

    (10) *Estimation of acid salts* by Leo's method.

(1) *Litmus test.*—Tested with litmus paper, the reaction should be acid, turning the paper red.

(2) *Congo-red test.*—Add a few drops of this dye to a portion of the stomach fluid. Free acids if present change it to sky-blue; acid salts produce no change.

(3) *Free HCl.*—To determine the presence or absence of this is of great importance to the physician, as it is as necessary for digestion as the pepsin itself, and its variation more important in diagnosis, *e. g.*, between cancer, in which it is diminished, and gastric ulcer, in which it is increased.

(*a*) Gunzburg's reagent $\begin{cases} \text{Phloroglucin} & . & . & \text{2 gr.} \\ \text{Vanillin} & . & . & . & . & \text{1 gr.} \\ \text{Absolute alcohol} & . & \text{30 gr.} \end{cases}$

A drop of this solution is added to a few drops of gastric juice and gently warmed. If free HCl be present in the smallest amount a red color is produced, and cherry-red crystals deposited.

(*b*) Boas's reagent $\begin{cases} \text{Resorcin (resublimed)} & . & . & \text{5 gr.} \\ \text{Sacchar. alb.} & . & . & . & . & . & \text{3 gr.} \\ \text{Spiritus dilut.} & . & . & . & . & . & \text{100 gr.} \end{cases}$

This test is about as delicate as the preceding and its ingredients not so rare and expensive. A few drops of the solution added to a little gastric juice in a dish and gently warmed produces a red color if free HCl be present.

4. *Uffelman's test.*—Add to 5 or 10 Cc. of a 2 to 5 per cent. solution of carbolic acid, 1 or 2 drops of ferric chloride solution and dilute with water till the solution assumes a beautiful amethyst-blue color; to this add a portion of the stomach fluid; a change to canary or greenish-yellow indicates lactic acid. This test is extremely delicate, holding for a 1 in 20,000 solution of lactic acid. Be careful to ascertain whether the patient has taken any wine or alcohol preceding the test, as either of these will give the same reaction.

(5) *Rennet ferment*, milk test.—Take a small quantity of boiled milk, say 10 Cc., having a neutral reaction, and add an equal amount of carefully neutralized filtered stomach contents. The mixture is then placed in a warm chamber at 100 F., and in 10 or 15 minutes the milk has coagulated and separated into a cake of casein and clear whey.

(6) *Butyric acid* decolorizes Uffelman's reagent. If present in large quantities, its acrid, rancid odor is manifest.

(7) *Acetic acid.*—The best practical test for this acid also is the nose. If present in considerable quantity it has an unmistakable odor.

(8) *Total acidity.*—The method of measuring this is simple. A burette is filled with a decinormal solution of caustic soda : 5 or 10 Cc. of filtered stomach contents are poured into a small glass beaker, and 1 or 2 drops of a (1 per cent.) alcohol solution of phenol-phthalein are added. The solution in the burette is very gradually added until the red color is just permanent. The number of Cc. of the alkaline solution used represents the acidity of the quantity of stomach contents employed. Normally the acidity of 10 Cc. of the stomach contents, obtained one hour after the test breakfast, is from 4 to 6 Cc. ; results below or above this are pathological.

(9) *Estimation of free HCl.*—This, provided no other free acids are present, is determined by adding pure chalk, which will neutralize the acidity if due to free acid, but has no effect on acid salts. The difference in acidity before and after the addition of the chalk represents the physiologically active HCl. To separate the organic acids, first extract with ether, by thoroughly shaking about 5 to 10 Cc. of the stomach contents in a medicine bottle with alcohol-free ether ; let the ether separate, which usually occurs very rapidly, and pour off in a small glass beaker. This is repeated until about 30 to 60 Cc. of ether has been used. The ethereal extract contains the organic acids.

(10) *Acid Salts.*—The last determination of acidity in the preceding test represents the quantitative estimate of acid salts.

FERMENTS.—These are certain nitrogenous bodies, animal and vegetable, of unknown constitution, which by some means, not clearly understood, cause many organic compounds to decompose, with the production of other and simpler substances, the ferments themselves being unaffected. Ferments are of two classes: Organized and Unorganized Ferments.

1. THE UNORGANIZED OR SOLUBLE FERMENTS.—Among these are: (a) *diastase* or *maltin*, appearing in the sprouting of grain, and formed from the gluten; it serves to convert the starch of the seed into glucose. Malt, which is sprouted barley, contains it in abundance, and is used to convert meal (starch) into glucose for fermentation in the manufacture of alcoholic liquors, and in medicine as a digestive agent. The ptyalin of saliva and a pancreatic ferment act like diastase, (b) *pepsin*, of the gastric juice, and (c) *trypsin*, of the pancreatic fluid, both of which serve to convert the albuminoids into peptones, the one in acid and the other in alkaline solution.

FIG. 75.

YEAST CELLS.

2. ORGANIZED FERMENTS.—When their spores are carried by the atmosphere, or otherwise, into a suitable fermentable liquid, viz., one containing albuminoid substance, and kept warm (68 to 105 F.), these ferments grow and proliferate wiih great rapidity, inducing fermentative changes in a few hours. The most important of these ferments are: (a) *Yeast* (*torula cerevisiæ*, or *saccharomyces eerevisiæ*), shown in figure 38. This converts glucose into alcohol and carbon dioxide (vinous fermentation); (b) *acetic acid ferment* (*mycoderma aceti*), commonly called " mother of vinegar," grows on solutions containing alcohol, which it helps to oxidize into acetic acid; (c) *mucor mucedo*, which causes alcoholic fermentation; (d) *thrush fungus* (oidium albicans) grows within the mouths of ill-kept children. It induces a slight alcoholic fermentation; (e) *lactic* and *butyric ferments* go together, the one preceding and the other closely following. These fermentations occur in intestinal indigestion, and the gas evolved produces flatulent colic.

Putrefaction (the spontaneous decomposition of nitrogenous organized bodies) is accompanied, if not caused by micro-organisms, usually bacteria. *Decay*, on the other hand, is the gradual decomposition of organic bodies by the slow action ot oxygen, and does not depend on living organisms.

Fermentation Experiment.—Before leaving the laboratory exercise, make a mixture of thin starch paste, crushed malt grains, and a bit of yeast. Put into a side-necked test-tube with its mouth corked, and the delivery tube dipping into a bottle of lime water. Next day note that the mixture has fermented, or is fermenting, and that the CO_2 evolved has bubbled out through the lime water, precipitating $CaCO_3$, and that the mixture is now alcoholic.

TABLE OF METRIC MEASURES.

Fig. 76.

The Décimètre.

MEASURES OF LENGTH.

1	Millimetre	=	0.001 of a metre.
1	Centimetre	=	0.010 of a metre.
1	Decimetre	=	0.100 of a metre	= about 4 inches.
1	**Metre**	=	**1.000 Metre**	= **39.37 inches.**
1	Decametre	=	10.000 metres.
1	Hectometre	=	100,000 metres.
1	Kilometre	=	1000.000 metres	= about ⅔ of a mile.
1	Myriametre	=	10,000.000 metres	= about 6⅛ miles.

MEASURES OF SURFACE.

1	Centaire	=	1 square metre	= about 1⅕ square yards
1	**Are**	=	**100 Square Metres.**
1	Hectare	=	10,000 Square metres.	= about 2½ acres.

MEASURES OF VOLUME.

1	Cubic centimetre	=	0.001 of a litre.
1	Litre (cubic decimetre)	=	1000. cubic centimetres.
1	Cubic metre	=	1000. cubic decimetres.
1	Cubic metre	=	1000. litres, or 1 kilometre.
1	Cubic metre	=	1 stere.

MEASURES OF WEIGHT.

1	Milligramme	=	0.001 of a gramme	= about $\frac{1}{65}$ of a grain.
1	Centigramme	=	0.010 of a gramme.
1	Decigramme	=	0.100 of a gramme.
1	**Gramme**	=	**1.000 Gramme**	= about 15½ grains.
1	Decagramme	=	10.000 grammes.
1	Hectogramme	=	100 000 grammes.
1	Kilo(gramme)	=	1000.000 grammes	= about 2⅕ lbs.
1	Tonneau	=	1000. kilos	= about 1 ton.

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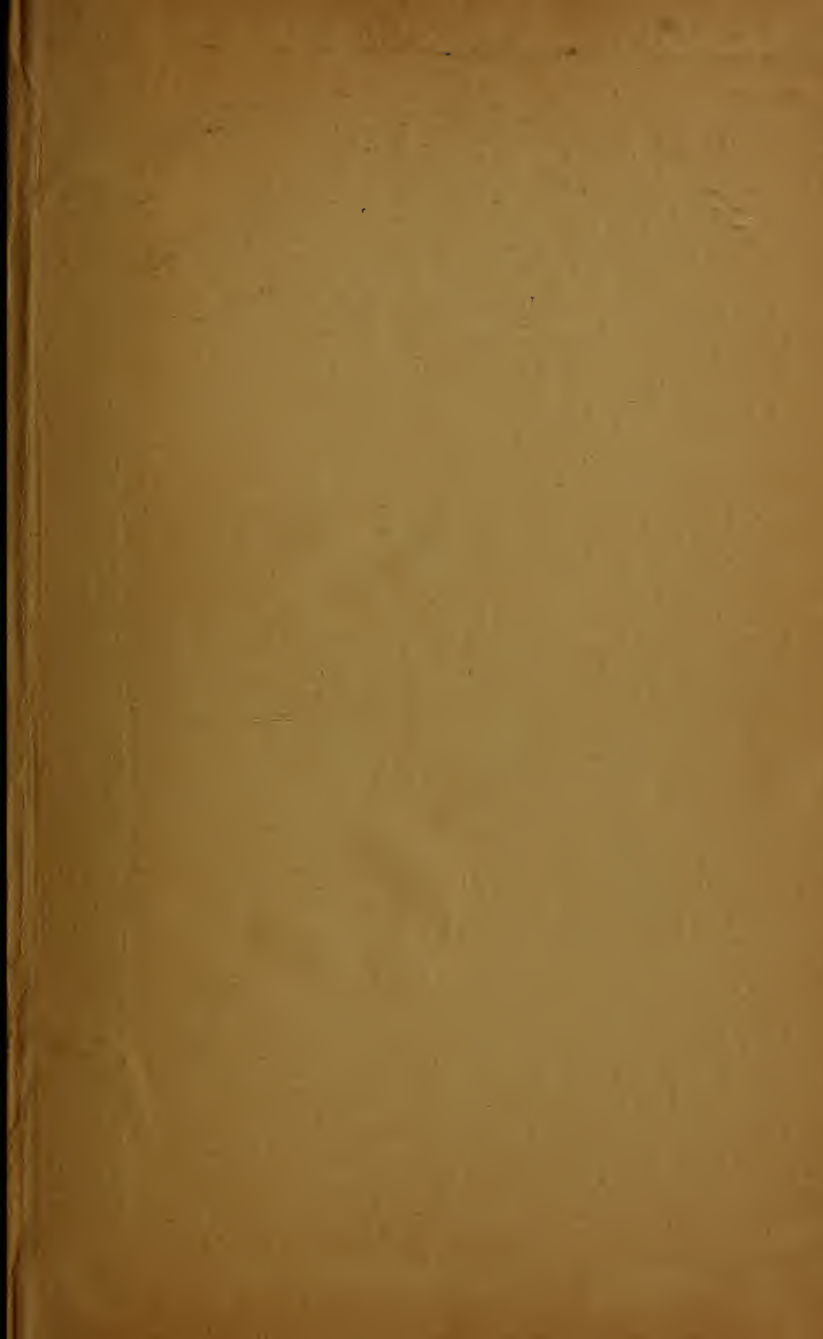**Second Edition,
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